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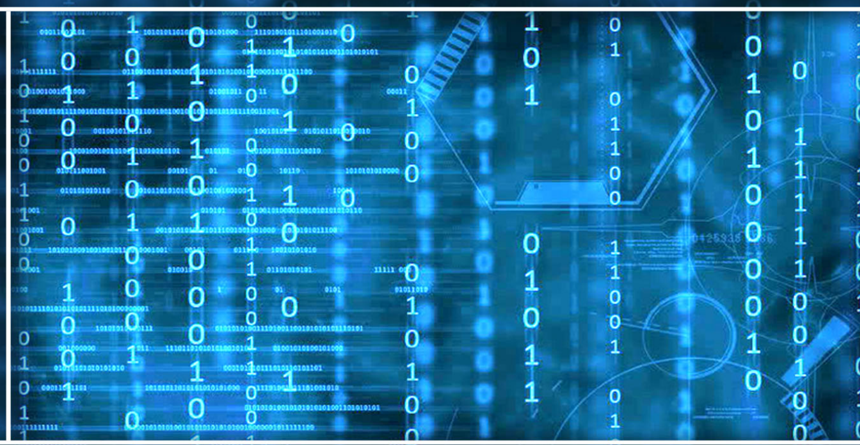

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Editorial Preface

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!

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Editorial Board

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Dependency Evaluation and Visualization Tool for Systems Represented by a Directed Acyclic Graph

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***Abstract*—There is a dearth of data visualization tools for displaying college degree-planning information, especially course prerequisite and complex academic requirement information. The existing methods for exploring degree plans involve a painstaking what-if analysis of static data presented in a convoluted format. In this paper, we present a data visualization tool, named as Dependency Evaluation and Visualization (DEV) chart, to visualize course prerequisite structure and a dynamic flowchart to guide students and advisors through all possible degree requirement completions. DEV chart uses an adjacency matrix of a directed acyclic graph to store a course structure for a degree into a database. Since DEV chart is created dynamically by updating data associated with each node of the directed graph, it provides a mechanism for adding an alert system when prerequisite conditions are not met, and hence the user can visualize the available courses at each step. Similarly, DEV chart can be used with project planning where nodes represent tasks and edges represent their dependencies.**

Keywords*—*Data visualization; degree planning; dynamic flowchart; prerequisite structure; adjacency matrix

I. Introduction

Many universities employ direct communications between academic advisors and students as the primary advising system [1]. Academic advisors are either faculty or professional advisors employed by an academic unit, and they typically help students make decisions about class schedules, select an academic major or minor, plan for graduation, and many other academic related activities [2]. These important decisions are made based on information stored in academic planning tools and offered courses in the upcoming semester. Curriculum changes are typically made once or twice a year so advisors need to spend time understanding and updating their knowledge about degree requirements and academic policies as well as familiarizing themselves with students' progress toward academic degrees prior to any advising period [3].

The most common academic planning tool is the Academic Advising Report (AAR) or Degree Progress Report (DPR) that consists of a list of degree requirements, a list of courses credited towards satisfying each requirement, an indication of whether each requirement is satisfied, and the remaining number of courses/units needed to satisfy each requirement. Many existing academic planning tools utilize static documents or PDF files for displaying information pertaining to degree requirements and course prerequisites. Design and implementation of a Learning Analytics Dashboard for Advisers, LADA, to support the decision-making process of academic advisers through comparative and predictive analysis is presented in [4].

Degree completion process shares many characteristics with project management. Projects are defined in terms of a set of tasks that must be completed in order to achieve the desired outcome. Task dependencies are comparable to course prerequisites: tasks may have multiple preceding tasks (prerequisites) and multiple succeeding tasks. Predecessor must finish before successor can start. Program Evaluation and Review Technique (PERT) [5-6] is a project management tool that is widely used to visualize the timeline and the work that must be done to complete a project. In PERT, all predecessor tasks must be completed before a task is started. One main difference between PERT and degree planning is that the tasks needed to complete a project are predefined whereas a major/minor can be completed by completing different sets of courses. Graphical Evaluation Review Technique (GERT) [7-8] is a project management tool that allows looping of tasks to allow tasks that need to be performed more than once. In GERT, a choice may exist where one of several tasks may be selected based on the associated probabilities.

Degree requirements vary in structure from one academic institution to another, and some of the requirements can be considerably complex. Major/minor requirements are often defined in terms of a set of course requirements that covers specific subjects or areas of knowledge. Choosing a major/minor, planning degree completion, and maintaining the progress towards completing a degree is a complex planning and scheduling problem. Integer linear programing model for finding academic plans that would satisfy a given set of graduation requirements and other constraints in the shortest possible time is presented in [9] and [10]. A student advising system using artificial intelligence techniques is presented in [11].

Many courses specify prerequisites that are outlined using a list of courses, all of which or a subset of which must be completed successfully in order to satisfy the prerequisites. In addition, a few of the prerequisites may be tied to course grades to ensure students acquire the necessary knowledge for getting the maximum benefit from the next course. A directed acyclic graph can be used to represent prerequisite relationships where nodes represent courses lists and edges represent their dependencies. Prerequisite relationships are often defined using one of, all of, either or, and, or a combination of those logical relationships.

There has been an interest in developing visualization tools for academic curricula and advising [12–18]. Moreno et al. [7] presented an interactive visualization tool for exploring course dependencies between courses. Prerequisite visualization has been studied by Aldrich [13]. His work was focused on the overall topology of the courses at Benedictine University, and he proposed a directed acyclic graph for representing prerequisite relations where each edge represents a logical relationship such as all of or one of. Chen et al. [14] presented an interactive course selection scheme with prerequisite hierarchy. Their work includes visualization of all of, one of, or either or logical relationships of courses offered at University of British Columbia. Zucker [16] presented a curriculum visualization tool for developing and arranging the flow of courses for a particular program. In this work, we create a data structure that can process any compound logical relationships. To our knowledge, there is no previous published work in which complex prerequisites structures have been investigated.

Dynamic data visualization tools directly influence the interpretability of visualizations [19-21]. There is a dearth of data visualization tools for displaying degree-planning information, especially course prerequisite information. None of the existing tools is capable of providing guidance on which of the available courses should be planned or when the available courses should be completed. Information pertaining to prerequisites are often scattered in various places, especially for hidden prerequisites. Therefore, planning and maintaining the progress toward completing a major/minor is a formidable challenge. The main objective of this paper is to introduce a novel data-visualization tool that is useful for academic advising as well as project planning where task dependencies play a major role.

Prerequisite visualization is challenging as defining an appropriate data structure for representing complex degree requirements and course dependencies is the most difficult part. Existing work is limited to most common types of degree requirements and prerequisite structures [13-14]. Since prerequisite structures and degree requirements vary from one academic program to another, it is important to identify an appropriate data structure that can process any complex degree requirement. Although we restrict this research to develop a data visualization tool for academic advising, the data structure introduced in this paper is useful for creating degree audit systems and other advising tools.

II. Data Structure for Degree Requirements

A. Degree Requirements

Most of the degree requirements are specified in terms of number of units, credits, or courses that must be taken to satisfy each requirement. There may be other requirements, such as GPA requirements, minimum number of credits/units needed to complete, internships, capstone projects, etc. First, we consider the degree requirements that are often expressed using one of the following terms:

- Complete a set of predefined courses.
- Select a subset from a set of eligible courses.
- Select a specific number of courses from each of several lists.
- Select a subset of lists and then select a specific number of courses from each of the selected lists (e.g., select two of three course lists and then select one course from each list).
- Select a specific number of courses from a selected subset of lists (e.g., select four courses from at least three different categories).
- Select courses with a specific total number of units from a list of courses.
- Select a specific number of units from a selected subset of lists (e.g. select at least five units from two different categories).

Requirements may refer to additional attributes such as course level (lower-division vs. upper-division) or student's minimum grade point average (GPA). In addition, some of the courses may not be taken until a minimum number of units has been earned. Courses may only count once in the major or minor, either as a required course or as an elective, but not as both. There may be hidden prerequisites (i.e. prerequisites of a prerequisite course that may not be explicitly listed as a part of any other requirements) and other requirements such as selecting major/minor emphasis areas.

First, we define a suitable data structure for evaluating degree requirements. A typical degree requirement belongs to one of the following categories:

- Type A: complete k courses from a set of p courses where $1 \leq k \leq p$
- Type B: complete at least m courses/units, but no more than n courses/units from a set of p courses where $0 \leq m \leq n \leq p$
- Type C: complete k units from a set of p courses where $1 \leq k \leq p$
- Type D: combination of Type A, Type B, and/or Type C requirements

Type A, Type B, and Type C degree requirements are relatively easy to implement but Type D requirements are often complex and difficult to implement. There may be other requirements, such as GPA requirements, minimum number of credits/units needed to complete, internships, capstone projects, etc. Those types of requirements can be treated separately by defining an appropriate data structure. Since degree requirements vary from one program to another, it is important to define a data structure that can represent any complex requirement. Such a data structure can be very valuable for introducing other useful advising tools.

B. Basic Requirements

In order to reduce the complexity of the model, we define a data structure to represent degree requirements.

Definition: A **basic requirement** is a 5-tuple (*A, T, m, n, δ*), where.

1. A is a set of objects,
2. T is the type of requirement (1:select number of objects, 2: select number of units),
3. m is the lower bound of courses or units,
4. n is the upper bound of courses or units, and
5. $\delta: A \rightarrow \{1, 0\}$ is a function such that $\delta(A) = 1$ if A is a credit-bearing set of objects and $\delta(A) = 0$ otherwise.

Type A, Type B, and Type C requirements defined in the previous section are basic requirements. Type D requirements can be represented using a set of basic requirements. Hence, requirements for any major/minor M_i are expressed as $M_i = \{R_{i1}, R_{i2}, \dots, R_{ir}\}$ where each degree requirement $R_{ij}(A, T, m, n, \delta)$ is either

a. a basic requirement where A is a set of courses or

b. a basic requirement where A is a set of basic requirements.

Let R_{ij}(A, T, m, n, δ) be a basic requirement. An object a_i (course or a basic requirement) satisfies a basic requirement R_{ij} if $a_i \in A$ belongs to A. We define a boolean function on A, $b_i: A \rightarrow \{1, 0\}$ such that $b_i(a) = 1$ if $a \in A$ and $b_i(a) = 0$ if $a \notin A$. A set $A = \{a_1, a_2, \dots, a_k\}$ satisfies a basic requirement R_{ij} if $m \leq \sum_{j=1}^{k} b_i(a_j) \leq n$.

Any set of degree requirements can be expressed using a set of basic requirements. Consider a set of requirements defined as follows:

R_1 : complete one of the courses $C1$ or $C2$

R_2 : complete all of the courses $C3, C4, C5$, and $C6$

R_3 : complete 6 units from the courses $C7, C8, C9$,

and $C10$

R_4 : Complete 6 – 12 units with at least two units in $A_1 = \{C11, C12, C13\}$, at least three units in $A_2 = \{C14, C15, C16\}$, and one unit in $A_3 = \{C17, C18\}$.

The requirements R_1, R_2, and R_3 are basic requirements where A is a set of courses. The requirement R_4 may be expressed using the two basic requirements R_{41}(A, T, 6, 6, 0) and R_{42}(B, T, 6, 12, 1) where

$A = \{R_6, R_7, R_8\}$

$R_6 = R_6(A_1, 2, 2, 2, 0)$: complete two units in A_1

$R_7 = R_7(A_2, 2, 3, 3, 0)$: complete three units in A_2

$R_8 = R_8(A_3, 2, 1, 1, 0)$: complete one unit in A_3

$B = \{C11, C12, \dots, C18\}$

Suppose M is any major that is expressed using a set of basic requirements $M = \{R_1, R_2, \dots, R_r\}$.Let C be the set of all courses available to satisfy requirements of the major M and C_i be the set of courses available to satisfy requirement $R_i \in M$. Then the number of courses satisfying the requirement $R_i(A, T, m, n, \delta)$ is $\sum_{k=1}^{l} b_i(c_k)$; credits counted for a requirement $R_i(A, T, m, n, \delta)$ is $s_i = \sum_{k=1}^{l} b_i(c_k) * n(c_k) * \delta$ where $n(c_k)$ is the number of units of the course $c_k \in C_i$; and the total number of credits counted towards completing the major M is $S_M = \sum_{i=1}^{r} S_i$ where r is the total number of requirements of the major M.

C. Sample Major Requirements

In order to illustrate the effect of the data visualization tool, consider a sample major $M = \{R_1, R_2, \dots, R_5\}$ with five requirements. Let C= $\{C1, C2, \dots, C25\}$ be the set of all courses available to satisfy requirements $R_1, R_2, \dots, R_5$.

Requirements are defined as follows:

R_1 : complete one of the courses $C1$ or $C2$

R_2 : complete one of the courses $C3$ or $C4$

R_3 : complete the courses $C5, C6, C13, C15, C17$, and $C25$

R_4 : complete 12 units from the courses $C8, C9, C10, C11$,

$C12, C14, C16, C18, C19, C20, C21, C22, C23, C24$

R_5 : Complete one of the courses $C7$ or $M11$

The set of courses available to satisfy each requirement is defined as

$C_1 = \{C1, C2\}$,

$C_2 = \{C3, C4\}$,

$C_3 = \{C5, C6, C13, C15, C17, C25\}$,

$C_4 = \{C8, C9, C10, C11, C12, C14, C16, C18, C19, C20,$

$C21, C22, C23, C24\}$, and

$C_5 = \{C7, M11\}$.

An appropriate subset of the set C = $\{C1, C2, \dots, C25\}$ needs to be selected to complete the major M. There may be other requirements associated with a major, such as unique requirements or minor requirements. Let us assume that there are two other unique requirements, U_1 and U_2 defined as follows:

U_1 : complete one of the courses $M8$ or $M9$

U_2 : complete one of the courses $C7$ or $M11$

Table I shows the prerequisite course structure for major requirements and Table II shows the prerequisite course structure for unique requirements.

A few of the prerequisite conditions are very complex, and some of the prerequisites are tied to course grades and courses from other disciplines. In general, prerequisites are completed, waived, transferred courses, or test scores that must be completed before taking a specific course.

The five requirements R_1, R_2,…, R_5 are basic requirements that are easy to implement, but the prerequisites are very complex, and there are many possible ways of choosing courses to satisfy prerequisites and major requirements.

TABLE I. PREREQUISITE COURSE STRUCTURE FOR MAJOR REQUIREMENT

		Requirements				
Courses	**Prerequisites**	R_1	R_2	R_3	R_4	R_5
$C1, C2$	$M2$ or $M3$, with a grade of C or better	x				
$C3, C4$	($C1$ or $C2$) *and* ($M4, M5,$ *or* $M6$), all with a C or better		x			
$C5$	$C1$ or $C2$			x		
$C6$	$C3$ or $C4$, with a grade of C or better			x		
$C7$	$M5, M7$ or $M8$, with a grade of C or better					x
$C8$, C9, C10	$C1$ or $C2$				x	
$C11$	$C3$ or $C4$				x	
$C12$	$C8$ and $C9$				x	
$C13$	$C6$ and ($C7$ or $M11$)			x		
$C14$	$C6$ and ($C7$ or $M11$)				x	
$C15$, C16	$C6$			x		
$C17$, C18	$C6$				x	
$C19$, C20, C21, C22, C23, C24	$C5$ and $C6$				x	
$C25$	$C5$			x		

Many existing academic planning tools utilize static tables like Table I or Table II for displaying course prerequisites. It is very difficult to understand complex prerequisite structures without drawing a directed graph.

D. Dependency Evaluation and Visualization (DEV) Chart

In this paper, we present a data visualization tool, which is named as Dependency Evaluation and Visualization (DEV) chart, to visualize course prerequisite structure. DEV chart uses an adjacency matrix of a directed graph D(V, E) to represent course structure where nodes (V) represent courses and edges (E) represent prerequisite relationships. Similarly, DEV chart can be used with project planning where nodes represent tasks and edges represent their dependencies. Tables I and II contain information needed to define adjacency matrices of the directed graphs for major requirements and other courses, respectively.

We define a Boolean valued prerequisite function $p: V \to \{true, false\}$ associated with the directed graph $D(V, E)$ such that $p(V) = true$ if prerequisite relation is satisfied for the course list attached to the node V, $p(V) = false$ otherwise. We also define a Boolean valued rotation function, $rt: C \to \{true, false\}$ such that $rt(c_k) = true$ if the course c_k is offered in the planning semester. Fig. 1 shows the DEV chart for major requirements, prior to completing any of the courses in the set C.

Fig. 2 shows DEV chart for unique requirements, prior to completing any of the courses. In Fig. 1, nodes with a stack of courses represent prerequisite courses where only one of the courses is needed to be taken to satisfy the prerequisite. If two or more arrows are pointing to the same child node, then each of the prerequisite relationships must be satisfied for the course list attached to the child node to be available.

TABLE II. PREREQUISITE COURSE STRUCTURE FOR UNIQUE REQUIREMENTS

Courses	**Prerequisites**
$M2, M3$	$M1$ with a grade of C or better
$M4, M5$	$M2$ with a grade of C or better or *M3* with a grade of B or better
$M6$	$M3$ with a grade of C or better
$M7$	$M5$
$M8$	$M4$ or $M5$, with a grade of C or better
$M9$	$M6$ or ($M5$ and $M7$), with a grade of C or better
$M11$	$M8$ with a grade of B or $M9$ with a grade of C

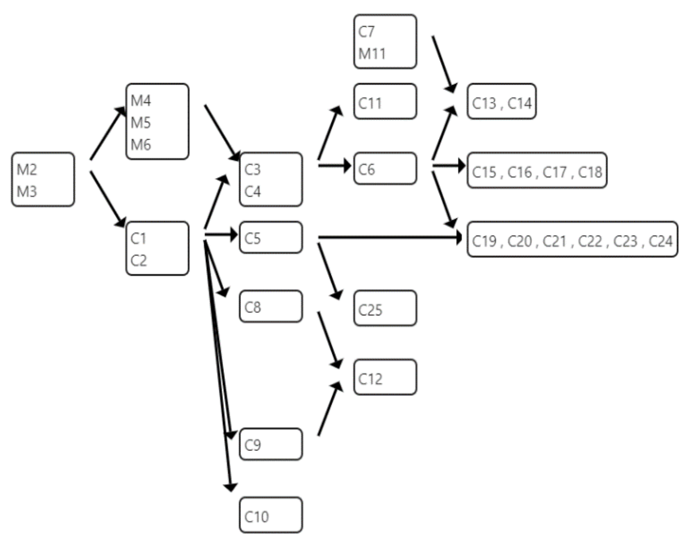

Fig. 1. DEV Chart for Major Requirements.

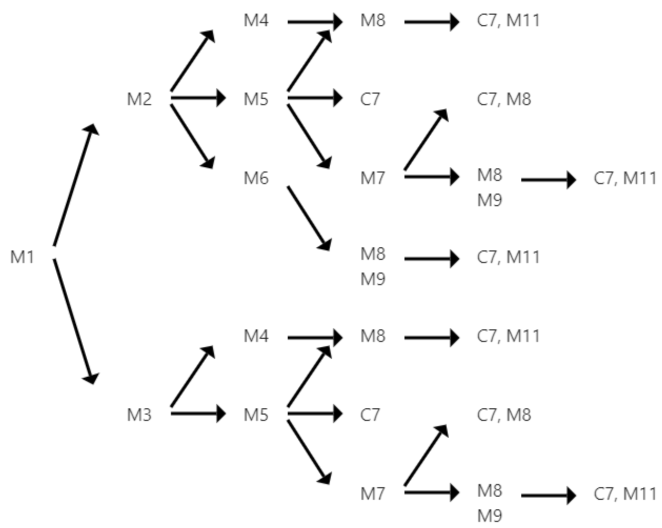

Fig. 2. DEV Chart for Unique Requirements.

TABLE III. MAJOR PROGRESS REPORT

Requirement	Satisfied?	Courses Taken	Courses Available
R_1	Yes	C1	
R_2	No	None	C3, C4
R_3	No	None	C5
R_4	No	None	C8, C9, C10
R_5	No	None	C7

When planning courses for a particular semester, students would normally have completed some of the courses required for the major and their prerequisites. It would be helpful to use a table similar to Table I to provide Academic Advising Report (AAR).

Table III shows the essential information that would be helpful for planning a major. It consists of a list of the major requirements, an indication of whether each requirement has been satisfied, and courses credited towards satisfying each requirement. The last column shows a list of courses available (prerequisites have already been satisfied) to satisfy the corresponding requirement, but not every AAR system has the capability to display such information.

The information in the last column of Table III is extremely valuable as it points to the courses that are available for planning the next semester. However, this information does not directly point to any bottleneck conditions that may prolong the graduation date. For example, students may plan the courses C8, C9, and C10 for the next semester and wait one more semester before taking either C3 or C4.

Note that the course C6 is a prerequisite for 12 of the 25 courses listed in Fig. 1. Hence, its prerequisites must be completed as soon as possible to minimize the time to complete the degree. Furthermore, courses C5 and C6 are prerequisites for six of the courses which are candidates for satisfying the requirement R_4. In this example, taking courses C5 and C6 would be the best choice for students seeking to minimize the degree completion time. The DEV chart is capable of conveying such useful information. Using degree progress report, the DEV charts in Fig. 1 and Fig. 2 can be updated dynamically to display the completed courses and the courses whose prerequisites have already been satisfied.

Fig. 3 and Fig. 4 represent an updated course structure, based on the completed courses and their grades. The color green is used to highlight completed courses whereas the color orange is used to highlight courses whose prerequisites are satisfied. Green arrows point to courses that are available to take in the next semester. Course grades are also displayed where * represents grades for the courses that are in progress and T represents transferred courses.

The course C13 is a required course for completing the requirement R_3, and its prerequisite is to complete C6 and either C7 or M11. Prerequisite for the course C7 is to complete either M5, M7, or M8, with a grade of C or better, whereas the prerequisite for M11 is to complete either M8 with a grade of B or M9 with a grade of C. Multiple paths exist for completing the prerequisite for the course C7 or M11. Based on the completed courses, the directed graph (Fig. 2) can be updated to narrow down the path choices.

Fig. 5 shows path choices after updating completed courses. DEV charts are created dynamically by updating data associated with each node of the directed graph. Hence, the DEV chart provides a mechanism for adding an alert system when prerequisite conditions are not met, as shown in Fig. 5.

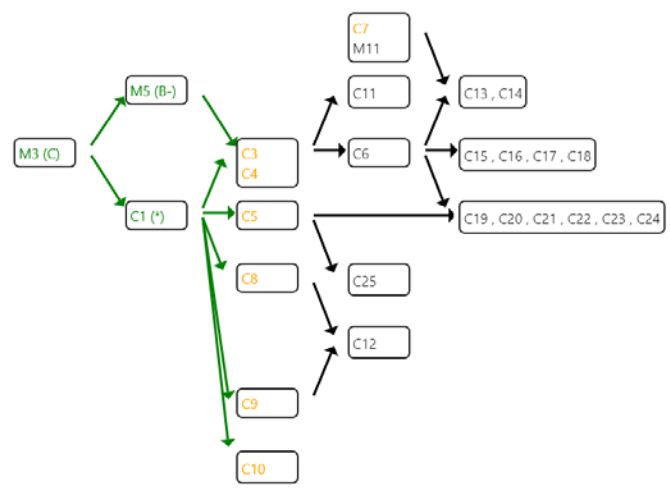

Fig. 3. Updated DEV Chart for Major Requirements.

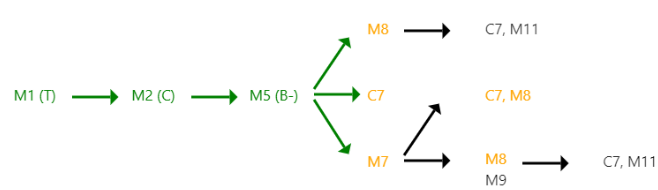

Fig. 4. Updated DEV Chart for Unique Requirements.

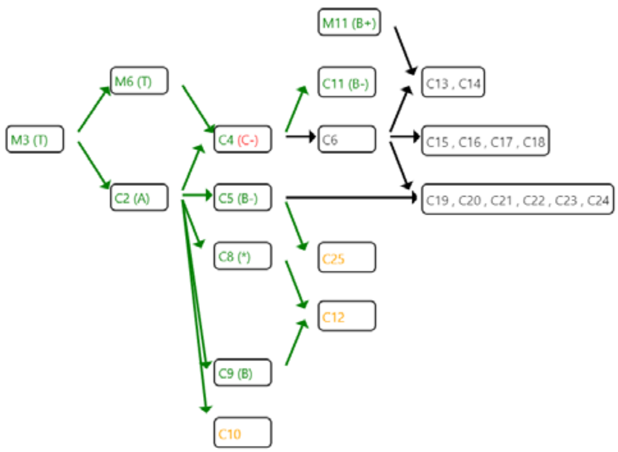

Fig. 5. Updated DEV Chart with Alerts for Major Requirements

The prerequisite for the course C6 is to complete either C3 or C4 with a grade of C or better, but the grade earned in this case is a C-, shown in color red, for the course C4. Subsequently, student has taken the course C11 that only requires a passing grade for C4. Instead of taking C11, the student should have repeated C6 for a better grade since C6 is a prerequisite for many other courses required for the major.

Most of the existing tools do not possess the ability to automatically alert a student as soon as the degree progress data or semester grades are updated. Therefore, many of the degree offering institutions rely on manual inspection to generate such alerts. The information displayed using a DEV chart can help students minimize degree completion time.

III. Implementation

DEV chart uses an adjacency matrix of a directed acyclic graph. We use custom-made tools to extract degree requirements and use basic requirement structure to store each requirement into a database. Similarly, we use custom-made tools to extract course descriptions and prerequisite relationships, and store the data using a format that is easier to process using any server-side scripting language. Course structure for a specific major is stored into a database using the corresponding adjacency matrix.

Fig. 6 shows the DEV chart that includes the major and unique requirements for Computer Science general emphasis major offered at University of Wisconsin-Whitewater (UWW). The DEV chart depicts the completed courses for an incoming freshman. In this example, student has earned credits for only one of the math courses (MATH 041) and eligible to take either MATH 139 or MATH 141.

Fig. 6. Course Structure for Computer Science Major General Emphasis at UW-Whitewater.

Fig. 7 shows the progress of the major requirements after completing some of the courses required for the major. Course grades are displayed where * represents grades for the courses that are in progress. The courses shown in orange are the courses whose prerequisites are satisfied. Green arrows point to courses that are available to take in the next semester. Note that COMPSCI 223 is a prerequisite course for most of the higher-level computer science courses. The prerequisite for 223 is a grade of C or better in either COMPSCI 220 or COMPSCI 222. In our test case, the student has earned a grade of C- for COMPSCI 220, as shown in color red. The red arrow associated with the course COMPSCI 220 is an indication that the student cannot take the COMPSCI 223 course until the prerequisite condition is satisfied. Such alerts can help students and advisors identify prerequisite issues. The Academic planning tool implemented at our institution does not have the ability to generate such alerts. Hence, these alerts can be very useful for academic advising.

Note that the COMPSCI 223 course is a prerequisite for many other COMPSCI courses that are either core courses or elective courses for the major. Therefore, students should make plans to take this course as soon as possible in order to graduate on time. It is difficult to identify such bottleneck courses without using a data visualization tool.

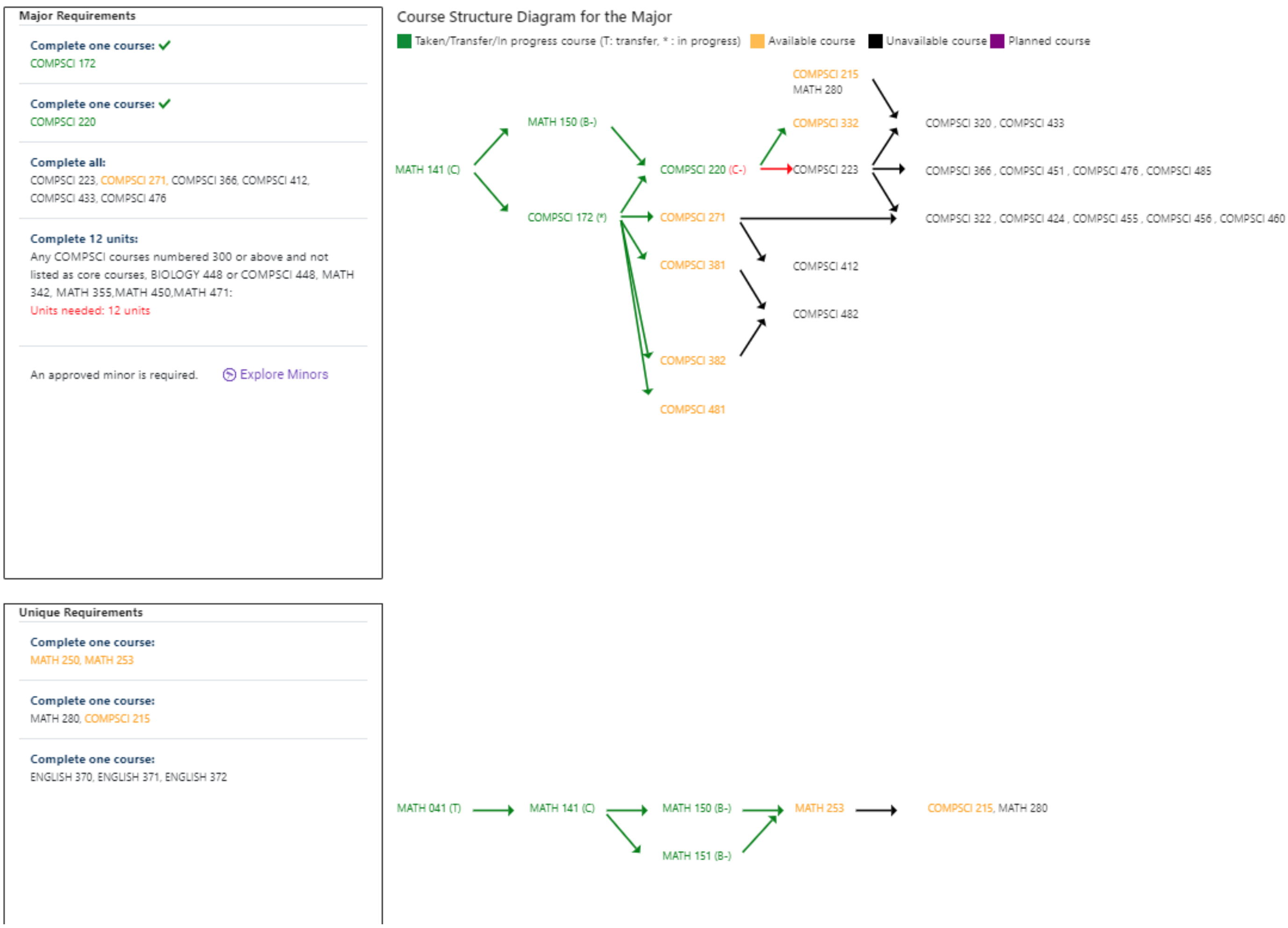

Fig. 7. Updated Course Structure for Computer Science Major General Emphasis at UW-Whitewater.

V. Conclusion and Future Work

We present a data visualization tool, DEV, for course prerequisite relationships. Our system is capable of interpreting one of, all of, either or, and, or any combination of those logical relationships. The implementation includes an interactive layout of major requirements and course relations.

Course prerequisites are very similar to task dependencies in project management. Completing the course prerequisites is similar to completing task dependencies: a task cannot be completed until the dependencies are completed. Hence, DEV chart can be extremely useful for project management where task dependencies play a major role. Furthermore, Dev charts can be useful for displaying information about graphs, such as cycles or specific branches/nodes satisfying a given criteria.

A pilot system has been successfully implemented for the Computer Science major offered at University of Wisconsin-Whitewater (https://cs.uww.edu/advising). This pilot system allows computer science majors to access an online advising system and interactively plan courses for their major, in consultation with their academic advisors. We are in the process of obtaining intellectual property rights for DEV charts.

The new data structure introduced in this research is extremely useful for analyzing student's academic progress toward a degree. We are exploring the possibility of developing a mechanism that would enable an undeclared student to explore requirements for all possible majors and explore the shortest path for graduation.

Acknowledgment

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"Dr.J": An Artificial Intelligence Powered Ultrasonography Breast Cancer Preliminary Screening Solution

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***Abstract*—Breast cancer ranks top incidence rate among all malignant tumors for women, globally. Early detection through regular preliminary screening is critical to decreasing the breast cancer's fatality rate. However, the promotion of preliminary screening faces major limitations of human diagnosis capacity, cost, and technical reliability in China and most of the world. To meet these challenges, we developed a solution featuring an innovative division of labor model by incorporating artificial intelligence (AI) with ultrasonography and cloud computing. The objective of this research was to develop a solution named "Dr.J", which applies AI to process real-time video live feed from ultrasonography, which is physically safe and more suitable for Asian women. It can automatically detect and highlight the suspected breast cancer lesions and provide BI-RADS (Breast Imaging-Reporting and Data System) ratings to assist human diagnosis. "Dr.J" does not require its frontline operators to have prior medical or IT background and thus significantly lowers manpower threshold for preliminary screening promotion. Furthermore, its cloud computing platform can store detailed breast cancer data such as images and BI-RADS ratings for further essential needs in medical treatment, research and health management, etc. as well as establishing a hierarchy medical service network for this disease. Therefore, "Dr.J" significantly enhances the availability and accessibility of preliminary screening service for breast cancer at grassroots.**

Keywords—Breast cancer preliminary screening; lesions detection; ultrasonography; artificial intelligence; deep learning; cloud computing; BI-RADS

I. Background

Breast cancer is one of the most common tumor diseases among women and causes millions of death every year globally [1]. In 2017, China recorded near 270,000 new breast cancer cases which continued to rank top among all the malignant tumors found in Chinese women. The average age of Chinese female patients is 49 while compared with over 60 in western countries. Moreover, growing incidences are reported in the younger age groups, and the incidences in the urban population are twice as high as the rural ones. Furthermore, women from higher education and income background also show higher incidences. The breast cancer pervasiveness is assessed to reach high since fewer than 60 cases according to 100,000 females matured inside 55-69 age to exceed 100 cases according to 100,000 females till the year of 2021 in China [2], with anticipated to reach at 2.5 million cases until 2021.

Although the universal health coverage in China growing quickly but put more pressure on low and middle income's cancer patients. In this review, only limited data statistics are included in national cancer registries for incidence and mortality because of breast cancer is about only 13 % of the nation-wide in China [3], distinction with 96 % patients in the USA and 32% patients in the European Union [4, 5]. Breast cancer growth is the most various diseases in the Chinese females which are accounted for by the GLOBOCAN with 21.6 cases per 100,000 females [6] as age standardized rate (ASR). Breast cancer is the more successive infection in the midst of urban females and the fourth most regular kind of disease in the wide open as per Chinese National Cancer Registry. On the other hand, specifically in central China, the ASR for the breast tumor is probably going as short to 7.94 cases per 100,000 females. In 2008, there were 16.6% patients revealed in China of having breast cancer matured within 65 age or senior (interestingly with 42.6% patients in USA).

It is assessed that by 2030, there will be 27.0% of patients with breast cancer [7] will remain accounted for matured at least till 65 ages. In Chinese females, breast cancer dangers are profoundly connected with realized hazard highlights for females in the high-salary countries [8]. The same to western females, hormonal and generative highlights, for example an extensive menstrual lifespan (primarily dependent on younger age at menarche and elder age at menopause), expanded phase from the outset alive work, invalid uniformity along with confined breastfeeding in view of not having more than normal kids—are connected differentially to build danger of breast malignancy in the Chinese inhabitants [9-12].

The benefit of mammography [13] stays uncertain in females with higher percentage in less than 50 age women. In other case, 57% of Chinese patients with breast malignant growth [14] are up-to 50 years old. A national screening program was endeavored in 2005 for breast malignancy with an objective of screening 1000 females with both mammography and ultrasound, however was ended as a result of absence of financing and worry about false-positive [15] determinations. Discoveries from an examination in Beijing [16] demonstrated that the solitary 5.2% of novel cases were

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distinguished by doing in-routine mammography, while 82.1% of ladies were analyzed clear side effects. However, recognized screening of breast malignancies was around 60% in USA [17].

II. Introduction

The survival rate for breast cancer is over 90% if found and treated in early stages and can overcome the leading cancer fatality rates in women. However, in China, only 15.7% of breast cancer patients were found when in BI-RADS category 1, while 44.9% and 18.7% were in BI-RADS category 2 and 3 respectively. Chinese women patients in relatively lower income and social background were normally at BIRADS category 3 and 4 when founded, while for those from higher income and social status, those females had BIRADS category 1 and 2 [18].

The increase in breast cancer fatality rate indicates an alarming situation amid highlights urgent need of developing a preliminary breast cancer screening system for the detection and diagnosis of breast cancer [19] available, accessible and affordable to the general public at community level. Current major screening and diagnosis methods include imaging, breast clinical exam and tissue sampling. Imaging tools include ultrasonography, magnetic resonance imaging (MRI), X-ray or mammography, and CT scanning. Finally, ultrasonography became our choice for the medical examination tool of our integrated solution. We excluded breast clinical exam, tissue sampling, mammography, MRI, and CT scanning for their inadequate sensitivity, invasiveness, radioactivity, high false positive rates, non-cost effectiveness, and high hardware installation threshold. These vulnerabilities or disadvantages, alone or combined, were detrimental to their promotion in community or grassroots scenarios.

Ultrasonography is physically safe, technically reliable and cost effective. Its ultrasound imaging will not cause invasive or radioactive damage as tissue sampling or mammography does. When examining dense breast that features Asian women figures, ultrasound has stronger penetration effect than mammography and thus better serves diagnostic accuracy. The procurement and maintenance costs and operation requirement of ultrasonography, which is radioactivity free, are also lower than other imaging tools such as MRI and mammography. The identification accuracy of breast masses detection of ultrasonography is 27% better than mammography [20, 21] among the women aged up to 50.

However, ultrasonography has its limitations. Its pixel quality is not as fine as other imaging tools and can be potential risk for missed diagnosis of small tumors. Its diagnosis accuracy is subject to influence from human factors including individual radiologists' experience and their physical and psychological status. In China, there exists an enormous gap seemingly impossible to fill amid very limited supply of breast cancer screening service by less than 130,000 ultrasonography radiologists against the demand by hundreds of millions of women, not to mention that these limited amounts of ultrasonography radiologists are also responsible for examination of other diseases.

In the past two decades, significant research work was done in an attempt to reduce the casualty rate of breast cancer and increase the accuracy of detection systems such as computer aided detection (CADs) [22]. CADs were introduced in different countries especially in United States. However, the effectiveness of diagnosis [23, 24] of various CADs is affected by their detection algorithms and database availability for processing and storing related medical images. There were a few systems developed in the past such as the Digital Database of Screening Mammography (DDSM), which was completed in the late 1990s. It was the main source for researchers to make image analysis of breast cancer. A database of ultrasonography imaging for breast cancer is not yet available in the world.

"Dr.J" becomes game changer by innovating a division of labor model for breast cancer screening that is empowered by AI, ordinary frontline staff without ultrasonography background, like average nurses or technicians, can finish the initial scanning and diagnosis of subjects, and the ones with suspected lesions detected by AI are filtered out for remote diagnosis confirmation by human ultrasonography radiologists. "Dr.J" minimizes the risks of misdiagnosis and missed diagnosis by thorough analytic processing of real-time ultrasound video feed, instead of sampled static images, at pixel level by AI. Its AI system can recommend categories for breast examination based on Breast Imaging Reporting and Data System (BI-RADS, which was developed and published by the American College of Radiology (ACR)) [25]. We also developed an automatic tracing system to ensure complete scanning of the entire breasts, take a snapshot of the location where the ultrasound probe detects the lesion, and display the location of the lesion with a clock position diagram. The operation of "Dr.J" is simple and does not require prior medical education or training background for its users. Since the diagnosis is made by deep learning, its diagnosis service is reliable, stable and almost infinite. "Dr.J" is integrated with a cloud computing platform that enables remote data processing and real time delivery of preliminary screening services. It also serves as a big data platform for storage of vast collected breast cancer screening data, such as patient information, lesions' images and BI-RADS classifications.

This innovative model significantly optimizes the utilization of constrained resources of ultrasonography radiologists and enhances the availability and accessibility of breast cancer screening services to the public, especially in communities. It also brings tremendous value with continuous improvement of the intelligence algorithms and neural networks as well as other in-depth utilization such as public and personal health management. It is China's first AI ultrasonography preliminary screening solution for breast cancer and AI Powered Regional Breast Cancer Tiered Medical Service Network.

III. Methods and Materials

A. Development of "Dr.J"

The development of "Dr.J" involved the technologies of deep learning, image processing, cloud computing, big data, computer vision and the object detection [26-34]. Fig. 1 indicates the design model for its development. It follows the track of capacity building for training deep neural network model for lesion detection and classifications, real-time processing of video feed of breast ultrasound, and a big data platform for the sharing and storage of information based on cloud computing.

- Convolutional Neural Networks (CNNs)

AI-enabled detecting and diagnosis of breast tumor are the essential values of "Dr.J" solution. To apply deep learning models to analyze medical images has been a topic of profound interest for researchers. Advanced artificial intelligence featuring algorithms and scientific neural models can be critical to the development of a breast cancer screening system and achieve breakthroughs in the machine detection and diagnosis of lesions. The deep learning and artificial neural networks have already matched and exceeded the human performance level as proved in a number of high-profile contests highlighted by Google's "Alpha Go". Rapid technology innovations have made neural networks stronger and learn faster.

Convolutional neural networks (CNNs) can be applied to develop AI-based screening and diagnosis systems and already proved effective in radiologist operation environment [35, 36]. There have been research done using different image analysis algorithms based on deep CNNs [37, 38] for image recognition and lesion detection for both mammography and ultrasonography [39- 41]. In this study, we formulated the operation and features of the ultrasound-based screening and applied CNNs to develop a set of algorithms for ultrasound image analysis featuring machine detecting and diagnosis of breast problems including malignant tumor, benign tumor, cyst and lymph nodes. It was trained with over 60,000 breast ultrasound images and tested on numerous real patients. A two-phase clinical validation of "Dr.J" has proved that its algorithms' reliability and accuracy matches human radiologists' level. To exclude operation risk of missed scanning of breast target areas, we also applied our own patent-pending visual tracing technology to use a camera to automatically track the ultrasound probe and display on monitor the scanned and remaining target areas. Such comprehensive smart capabilities based on AI and other advanced IT technologies can effectively empower staff in community clinics where radiologist services are usually not available.

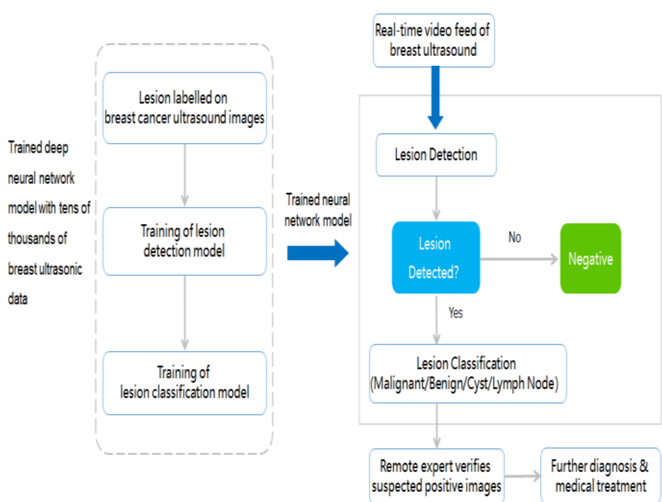

Fig. 1. Designed Development Model of "DR.J".

- Real-time Processing of Video Feed of Ultrasound Images

Along with the training of a neural network model for lesion detecting, we also worked on its capability for real time processing video feed of the breast ultrasound images. The system needs to decode live ultrasound video feed, whose frequency is 24-32 image frames per second (FPS) for digital image processing and object detection as shown in (Fig. 2). The deep convolutional neural network would further analyze each single decoded image, identify and highlight the malign tumor, benign tumor, and cyst as well lymph node. This real time processing keeps repeating until the breast scanning is finished.

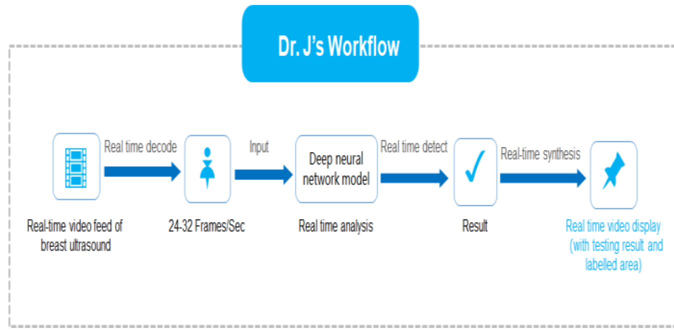

Fig. 2. Real-Time Processing of Ultrasound Video feeds by "DR.J".

Comprehensive coverage significantly contributes to the reliability of "Dr.J". The ultrasonography scanning of a subject normally takes five to ten minutes. During this process, at least 7,200 and more ultrasound images from the live video feed are thoroughly processed real time by "Dr.J". The neural network of "Dr.J" has a strong generalization ability that can intelligently recognize and process ultrasound images from various machine models manufactured by different companies. In comparison, former currently available AI powered analysis of X-ray, CT and MRI only examines much smaller numbers of samples ranging less than 1000 static images in a non-real-time mode. Furthermore, "Dr.J" computing analysis of images is conducted at the finest possible level of pixels. All these strengths maximize the examining coverage of the targeted areas and minimize the risk of missed diagnosis.

B. Training of Lesion Identification and Classification Model

The next thing to train was the lesions identification and classification model. When processing live video feed, the neural networks of "Dr.J" diagnose the detected lesions. It can identify four types of breast health problems, namely, malignant tumors, benign tumors, cysts and lymph nodes. It is an essential capability of "Dr.J" to detect tumors and make initial judgment of their malignant or benign status, cystic or solid status as well as their BI-RADS classifications. Detected lesions will be highlighted in rectangular shapes together with side indication of its nature as judged by AI. If AI detects no lesion, the system would see its subject as healthy and not alert it for further processing; however, if a lesion is diagnosed, the lesions classification functions would perform in accordance with BI-RADS. "Dr.J" sets four categories of BI-RADS classifications from Category 1-4 depending on their malignant or benign status, cystic or solid status, and size of lesions. BI-

RADS Assessment Categories include seven categories: 0) Incomplete information to diagnose; 1) Negative, means healthy; 2) Benign finding(s); 3) Probably benign; 4) Suspicious abnormality; 5) Highly suggestive of malignancy; 6) Known biopsy—proven malignancy.

For the purpose of preliminary screening, we exclude Category 0, and combine Category 5 with Category 4, since as long as a subject is classified as either Category 4 or Category 5, the subject definitely needs to have further examination, and it does not make too much difference in the scenarios of preliminary screening. We exclude Category 6 too, since Category 6 will be classified only after biopsy. "Dr.J" would alert such findings for consideration of further processing including radiologist review and tissue sampling. (Fig. 3) shows the BI-RADS classifying. The detected lesions found in a subject will be displayed with description of its size and locations.

- Clinical Verification of Solution's Detection and Diagnosis Capabilities.

"Dr.J" went through two phases of clinical validation conducted in Duanzhou District Women and Children's Hospital, Guangdong, China.

In the first phase as indicated in Fig. 4, the examination of subjects is performed by the same ultrasound equipment and the same radiologist, the ultrasound video live feed was analyzed by the radiologist and the AI system of "Dr.J" simultaneously, the results from radiologist was compared with the results from "Dr.J", and both suspected positive results were verified through biopsy.

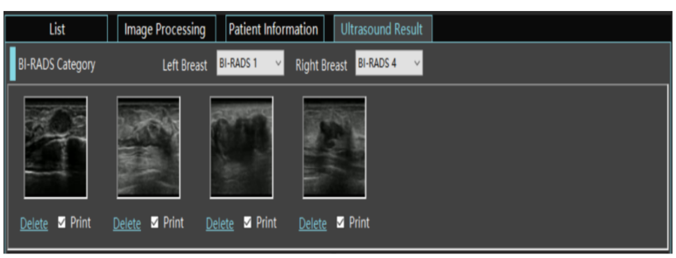

Fig. 3. BI-RADS Classification by "DR.J".

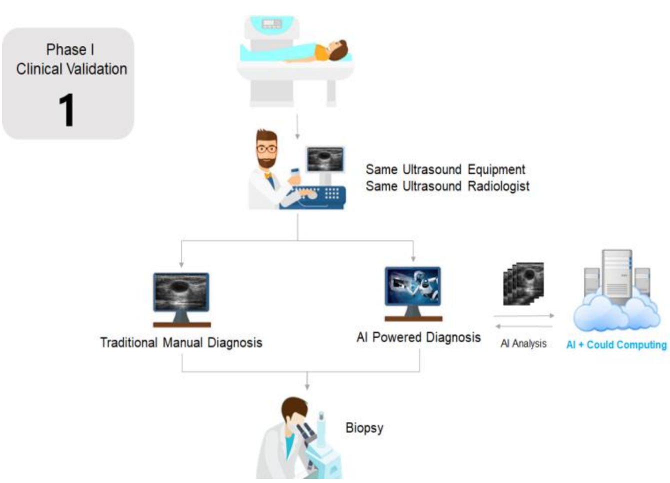

Fig. 4. Phase-I Clinical Validation with Same Equipment and Same Operator.

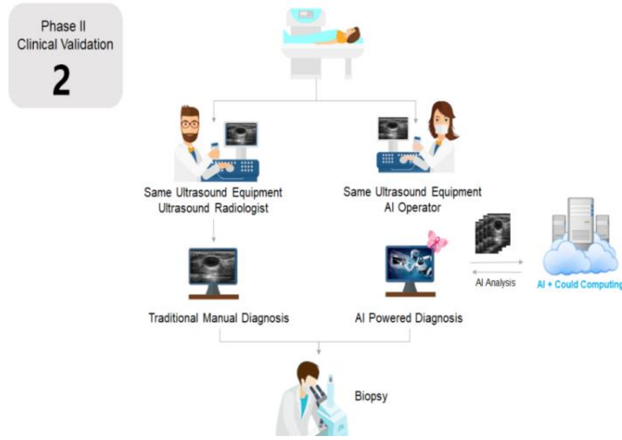

Fig. 5. Phase-II Clinical Validation with Same Equipment and different Operators.

Fig. 5 represents the second phase of validation in which breast ultrasonography examination was still conducted by the same ultrasound equipment. At the first step, a radiologist examined the subject, and at the second step, a non-radiological operator scanned the subject's breasts under the surveillance of "Dr.J" and the ultrasound data was analyzed by the AI system of "Dr.J". The results from radiologist were compared with the results from "Dr.J", and both suspected positive results were verified through biopsy.

C. Big Data Platform Based on Cloud Computing

Another highlight of "Dr.J" is its big data capability supported by cloud computing technologies for efficient and effective sharing and storage of breast health information. In ''Dr.J'' solution, breast cancer screening data are stored and processed with cloud computing for data sharing, and big data analysis. The information normally includes a subject or patient's age, gender, name, ID number, living place, captured images of lesions, types of lesions, locations of lesions, recommended BI-RADs ratings of breasts, and the time of conducting the screening, etc. The scope of collected data can be extended to include other related information such as family breast cancer history, dietary preference, career background etc. to serve further public and personal health management and scientific research desires. Furthermore, the number of images collected from a subject varies and depends on her health conditions of breasts. The collection of lesions information includes their locations and sizes of lesions (width, height, area). For healthy breasts, no image will be captured. The captured images of lesions are saved in the format of .JPEG format. Such information can also be downloaded and printed from the system. Multiple lesions can be detected on one ultrasound image.

For each frame with lesion detected, a group of three images are captured, one image is the original ultrasound frame without any labeling by AI system, one image is the image with labeling by AI system, and one image is the clock position diagram generated by ultrasound probe tracing system when lesions detected, which demonstrates the positions of lesions. This information facilitates the quick detection of lesions in the follow-up examination by physicians.

Supporting by infinite storage space in cloud, “Dr.J” can save huge amount of information for future development including image analysis and statistical analysis [30]. The database can efficiently filter the data including detected images according to desired query. They can also serve the continuous deep learning of the various neural networks of “Dr.J.” Convenient information sharing that is enabled by cloud computing gives radiologists’ convenient remote access to the breast cancer screening data. The ultrasound images with lesions detected by “Dr.J” are uploaded with lossless compression to the data repository on the cloud, and as a quality control means, remote radiologists can download and verify these images with lesions. Fig. 6 indicates a radiologist’s remote examining of images with suspected lesions as detected and displayed on her end by “Dr.J”.

After the preliminary screening performed by “Dr.J”, an AI Breast Cancer Preliminary Screening Report will be generated automatically by “Dr.J”, as shown in Fig. 7, which displays the images with detected breast cancer lesions, and the BIRADS categories for both breasts suggested by the system.

This AI Breast Cancer Preliminary Screening Report can be accessed on smart devices via social media application of Wechat which is the most popular social app in China. After the preliminary screening performed by “Dr.J”, an AI Breast Cancer Preliminary Screening Report will be generated automatically by “Dr.J”, as showed in Fig. 9, which displays the images with detected breast cancer lesions, and the BIRADS categories for both breasts suggested by the system. This AI Breast Cancer Preliminary Screening Report can be accessed on smart devices via social media application of Wechat which is the most popular social app in China.

D. *“Dr.J” in Operation*

Fig. 8 is the workflow diagram of the solution. Before the breast cancer screening, “Dr.J” system needs to be connected to the ultrasonography equipment in healthcare institution to receive ultrasound video feed from the ultrasonography equipment.

During the screening, “Dr.J” will analyze the breast ultrasound video signal, the ultrasound images will be captured and labeled when lesion is detected, compressed with lossless algorithm and uploaded to the data repository on the cloud. Remote radiologists or physicians can download the breast cancer screening data for quality control verification or referral of medical treatment.

Fig. 6. Remote Verification of Suspected Positive Images.

Fig. 7. AI Breast Cancer Preliminary Screening Report.

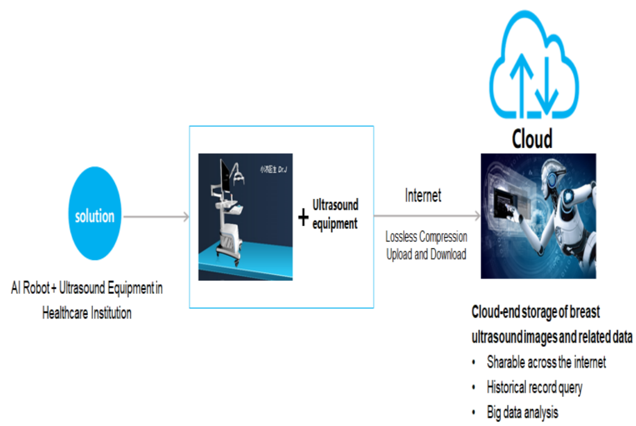

Fig. 8. Workflow of "Dr.J".

IV. Breakthroughs Achieved by “Dr.J”

‘‘Dr.J” innovatively reshapes the division of labor in preliminary breast cancer screening and significantly enhances the availability and accessibility of such service in communities. Its AI-enabled diagnosis capability successfully lowers the threshold for preliminary breast cancer screening and empowers frontline manpower. In traditional screening model, breast scanning and diagnosis are conducted by the same radiologist who has to screen all subjects equally no matter she has or has no breast health issues, in order to filter out the ones with breast health issues. Such practice is not an effective use of the valuable time of ultrasonography professionals who are in great shortage, especially when the majority of screening subjects are healthy and only very few of them have suspicious breast masses that need radiologists’ intensive attention. With “Dr.J” solution, the labor-intensive breast preliminary scanning and upfront software operation can be performed by average people who are not required to have medical or IT background. These people can fulfill the frontline tasks after receiving a few hours of training.

The preliminary diagnosis of screening subjects is conducted by solution's neural network. Only the cases with suspected positive results will be sent to radiologists for further processing. Therefore, "Dr.J" maximizes the value of radiologists by focusing their professional diagnosis service on those who are most needed. Consequently, in proportion to the patients with breast health issues, the number of subjects that a radiologist can effectively cover multiples exponentially when compared with the traditional screening practice as indicated in Fig. 9.

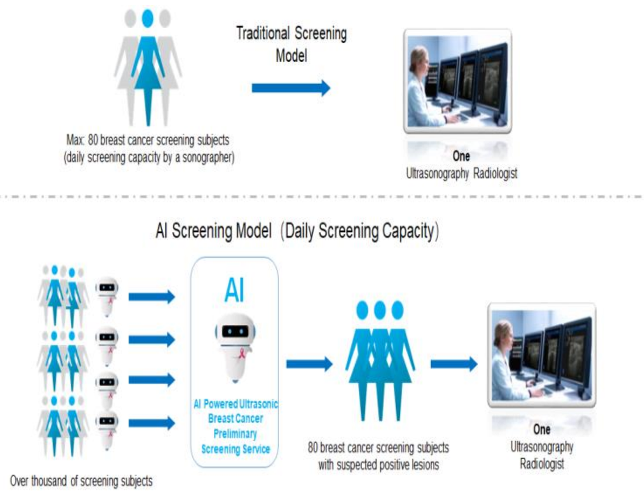

Fig. 9. Lowering Manpower Threshold using ''Dr.J''.

The ''Dr.J'' system makes possible the establishing of a tiered hierarchy medical network for breast cancer screening, diagnosis, treatment, recovery, and follow-up checkup as shown in Fig. 10. Such network comprises community health service providers at the grassroots, regional centers at the higher level, and medical institutions such as general and specialty hospitals at the top.

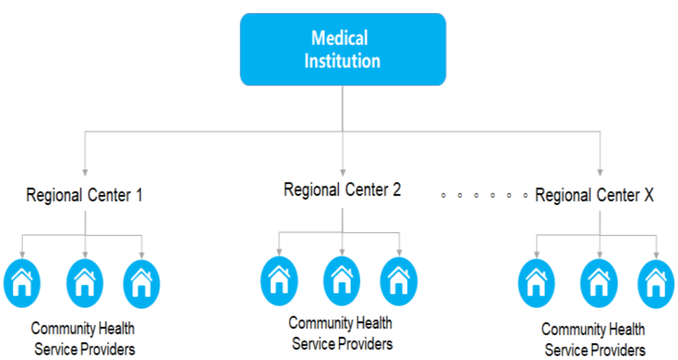

Fig. 10. Hierarchy Medical Service Network for Breast Cancer.

In such a network, preliminary screening can be conducted by normal staff at community clinics by using "Dr.J." When a suspected tumor is detected, via the cloud computing platform of "Dr.J", the community health service providers at grassroots can refer the case to radiologists stationed in regional center for remote or site diagnosis. When the positive result is confirmed, the patient can be further referred to general or specialty hospital for medical treatment. When the treatment is completed, the hospital can refer the patient back to a community clinic for rehabilitation where the patient will be monitored periodically by "Dr.J". The two layers of regional center and medical institution can be combined into one depending on local resource availability and needs. "Dr.J" is a digital big data platform for efficient information storing and sharing for this complete screening-treatment-recovery ecosystem of breast health managements.

The ''DR.J'' system can be used in diverse scenarios, including community health service provider centers (normal clinics), beauty parlors, mobile screening stations (ambulances) and the community mobile breast cancer preliminary screening operators as presented in Fig. 11. The experts can remotely access related information such as images and suggested BI-RADS classifications and provide their diagnostic feedback via "Dr.J" cloud platform. "Dr.J" also has both Chinese and English language versions. It can not only serve women in China but also other areas in the world. For further information, one can contact by the given website link (http://www.800ai.com).

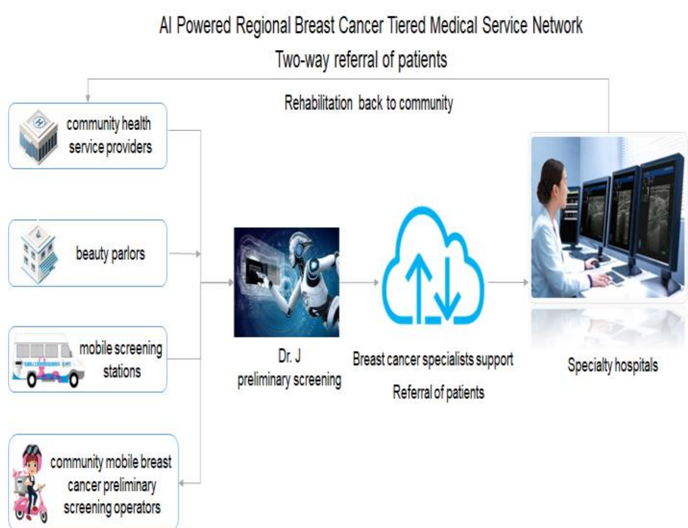

Fig. 11. "Dr.J" usage in Multiple Scenarios.

V. Results

During the evaluation of the neural networks of "Dr.J", deep learning based captured tens of thousands of breast cancer ultrasonography images are used and results shows that the developed solution is capable to efficiently identify the breast lesions of breast cancer patients. The data was collected from several hospital partners including Duanzhou District Women and Children's Hospital, Guangdong, China. These images were labeled by radiologists with lesions of various breast problems highlighted.

To achieve valuable sensitivity and specificity, it also involved distinguishing lesions from normal tissues like fat, gland etc. For the training and testing of the neural networks, the training images are in .PNG format and their size formats are set at 300x300 pixels. The training also involves application of advanced computer vision and object detection techniques. Its calculation is based on pixel level of the images. Fig. 12 indicate the successful lesion detection by "Dr.J."

There has been constant feeding of newly labeled images to the trainings of detection model. Its accuracy and reliability of detection have consistently improved from repeated learning and training of more images. We have captured all images with related information of exact time and location during the screening process as shown in Fig. 13.

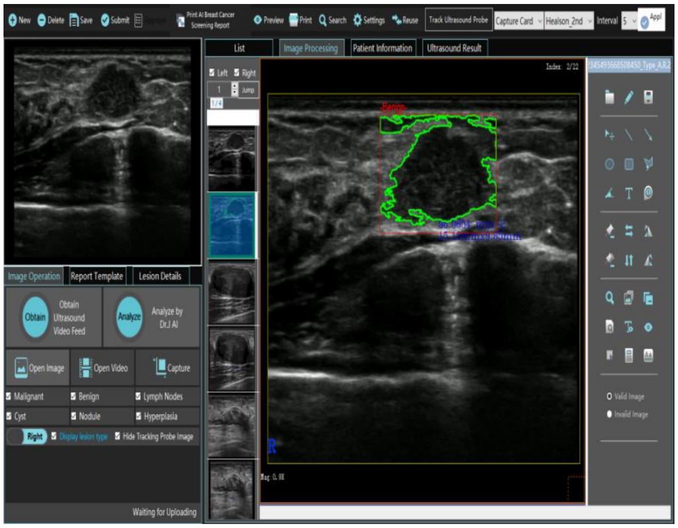

Fig. 12. Illustration of Lesions Detection.

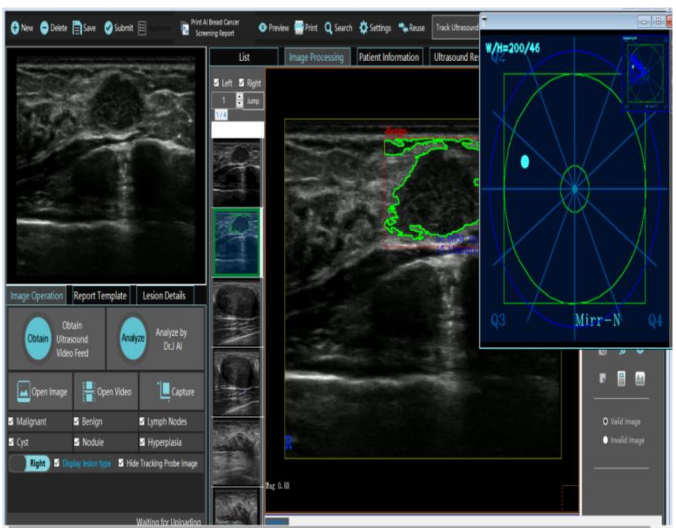

Fig. 13. Lesion Location on a Clock Diagram.

VI. Conclusions

"Artificial intelligence + Internet + Cloud computing + Ultrasonography" can effectively break the bottleneck of insufficient large screening capacity, addressed the irregular availability and quality of existing breast cancer screening services, and empower community clinic staff. It greatly optimizes the utilization of professional service resources to let radiologists' focuses on where they most needed. It will effectively minimize the risks and costs from women's exposure to and treatment of the deadly breast cancer.

In future, with the growth of data processed by "Dr.J," its detailed labeling of detected lesions, suggested BIRADS classification, structure of neural networks and its performance will be conferred in depth. As a result, its accuracy and reliability will continue to improve and can help in serving most of the women. The model of "Dr.J" can not only be applied in the combat against breast cancer, but will also be used for preliminary screenings of other diseases such as thyroid cancer.

Author Contributions

Conceptualization, Z.Z.[1] and Z.A.[3]; methodology, Z.Z[1] and Z.A. [3]; software, Z.Z. [1], Y.Z. [1] and D.Y.[1]; validation, X.X. [2], F.Z.[1], D.Y. [1], Y.Z.[1] and M.N.[1]; formal analysis, M.N.[1], D.Y.[1], X.X.[2] and F.Z.[1]; investigation, Z.Z.[1]; resources, Z.Z.[1], F.Z.[1] and Z.A.[3]; data curation, X.X.[2], F.Z.[1]and Z.Z.[1]; writing - original draft preparation, M.N.[1] and Z.Z.[1]; writing - review and editing, M.N.[1], F.Z.[1] and Z.Z.[1]; visualization, Z.Z.[1], D.Y.[1], Y.Z.[1], M.N.[1], and Z.X.[1]; supervision, Z.Z. [1]; project administration, Z.Z.[1], Z.X.[1] and Y.Z.[1]; funding acquisition, Z.Z.[1] and F.Z.[1]. All authors have read and agreed to the published version of the manuscript.

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Porting X Windows System to Operating System Compliant with Portable Operating System Interface

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***Abstract*—Now-a-days graphical interface is very important for any operating system, even the embedded ones. Adopting existing solutions will be much easier than developing your own. Moreover, a lot of software may be reused in this case. This article is devoted to X Window System adaptation for Portable Operating System Interface (POSIX) compliant real-time operating system Baget. Many encountered problems come from the tight connection between X and Linux, therefore it is expected to encounter these issues during usage of X on non-Linux systems. Discussed problems include, but not limited to the absence of dlopen, irregular file paths, specific device drivers. Instructions and recommendations to solve these issues are given. A comparison between XFree86 and Xorg implementations of X is discussed. Although synthetic tests show Xorg performance superiority, XFree86 consumes fewer system resources and is easier to port.**

Keywords*—X Window System; X11; X.Org Server; Xorg; XFree86; Portable Operating System Interface (POSIX); graphics; Realtime Operating System (RTOS)

I. Introduction

Although some real-time operating systems have not included graphic output for a long time, it's absence or obsolescence may be a huge disadvantage nowadays. Many target devices, such as onboard computers in cars or aircrafts, started to utilize displays for showing gauges and providing additional information to the user. In order to support this features, RTOS must provide some graphic API for applications. Options are limited to adopting existing interfaces or writing your own. The most straightforward solution to this problem - development of your own interface will allow you to minimize API overheads, which may be very crucial for embedded devices. Major disadvantage of this approach will be low portability of used applications. Also a lot of existing applications must be ported manually in order to use them. On the other side, adopting common graphic solutions will result in decreasing development cycle time by acquiring updates and tests from community and standardization of API usage for software. However, some problems will be encountered during porting. Moreover, it may be hard to further improve this software in terms of performance due to adopted architecture.

Host real-time operating system is called Baget [1]. It provides different standards for developers: POSIX 1003.1 [2], ARINC 653 [3], C++11. All programs must be statically compiled in order to run. Baget focuses on system reliability: many self-test facilities are implemented, including, but not limited to tasks and OS automatic restart, stack overflow checks, object validation. Baget can run various tasks simultaneously with separated process contexts [4]. Current graphical subsystem is server-client X windows system implementation named XFree86 with version 4.8.0. Although XFree86 [5] supports up to the X11R6.6 protocol version, which is barely enough to run modern applications, absence of many important extensions, for example, Xrender [6], implies heavy limits upon software.

Nowadays existing free software solutions in display servers for operating systems are limited to two options: X Windows System and Wayland [7]. However, there is a big ideological difference between them. X started it's history a long time ago in the '80s and was developed as an all-around solution. The protocol supports a lot of operations, including window management and draw operations. For example, it is possible to implement an application menu via X11 calls. Although X API is rich, nowadays a lot of software does not use it directly due to its complexity. Over time a lot of frameworks emerged upon X, for example, GTK. As a lot of frameworks implemented its API and draw capabilities, drawing directly through X become obsolete. Moreover, some server capabilities were moved into kernel, for example, User Mode Setting became Kernel Mode Setting [8], [9]. To replace X, which has a lot of excessive functionality and complexity, Wayland was created. Its protocol is completely unaware of window content and does not support any API that allows drawing your application. The scope of Wayland is window interaction, buffer management, etc. To fill window content you need to use another API or framework, for example, Qt, EGL, or even X. Although Wayland is considered to be a better display server protocol (mostly because it is created in a way to be a window system and nothing more), it's implementations are highly dependent on relatively new Linux kernel API named Direct Rendering Infrastructure [10]. Adopting these interfaces will surely become a difficult task. As for X, although its modern implementation Xorg also can use new Linux kernel subsystems [11], it still supports less complicated backends. Moreover, not only all modern frameworks are ready to be used with X, old software is compatible with modern server implementations. Considering all these arguments it was decided to adopt a modern window manager called X.org [12]. It was forked from the XFree86 project in 2004. Nowadays X.org, which is widely used in the most popular Linux distributives, is de facto standard X11 implementation with frequent updates. In comparison to it, XFree86, which is the current Baget OS windowing system, was released in 2008.

The main objective is to adapt the newest X.org version to Baget to be able to use the whole X ecosystem, including modern codebase and libraries. Although X uses a client-server architecture, most porting problems come from the server-side. It is divided into two parts: Driver Independent X (DIX) that represents server logic, request processing, drawing routines, extensions, etc., and Driver Dependent X (DDX), which is responsible for handling hardware, input and output devices and holds most of OS-specific code. To be able to use Xorg with the operating system, or rather API, that is not supported by developers, matching DDX must be implemented. Codebase already has some implementations for Linux, Wayland, Windows, etc. However, they are dependant on API that generic POSIX-compliant OS might not have. Of course, writing new DDX from scratch would be the best way in terms of compatibility, but time and resources spent on this will be huge. On the other hand, patching the present code would reduce the initial workload in exchange for testing. As a base of our solution, we decided to use the existing DDX for Linux systems. Obtained during this research solutions and recommendations may be used to port modern X to another operating system with similar to Baget properties, because a lot of encountered problems will arise during adaptation to any non-Linux based OS.

In addition to that, issues regarding XFree86 adaptation will be considered, as well as performance and system resource usage in comparison to modern X.org.

To sum up, there are two main questions:

1) How to port Xorg to Baget OS and what problems are expected to arise with other POSIX-compliant systems?
2) Is it worth to port Xorg instead of xFree86?

This paper is organized as follows:

- A review of issues that arise when porting X server to new operating system with constrained functionality and proposed solutions.
- Performance comparison between XFree86 implementation and modern Xorg implementation.
- Conclusions and future work.

II. Related Work

Although X Window System was developed in 1984, there is a shortage of available articles and proceedings that discuss various aspects of the protocol and implementations. Discussion is primarily done on specialized forums and mailing lists. Most articles were done in the 90's and discussed earlier versions of X protocol. Even less information can be found on porting X Window System implementations to operating systems, other than Linux.

Recent publications on X Window System discuss general programming issues that arise when using X11 API [13]. Performance is critical for the windowing systems, so a lot of work is done on using GPU acceleration for drawing operations to reduce CPU workload. In [14] authors try to reduce cpu overhead by implementing resource-sharing protocols. Some attempts on porting X server implementation to embedded system result in a practically complete overhaul of the server internal systems [15].

III. Portability Problems and Solutions

A. Static Compilation

In the Baget OS, processes are pre-defined and starting along with the system itself. Due to this, executable code cannot be loaded dynamically. This requires all of the process code to be packed into a single object file during system compilation.

Although machine independent part of the X.org server can be statically built with ease and have a corresponding option, some problems come from the DDX component. It is necessary to change makefile scripts and rename entry point function to be able to call it later.

Another problem comes from X architecture. Nowadays, two sets of libraries are used to build X infrastructure. Ones are required by the server-side, ones by client applications. Some libraries as libXau are used in both. But others may have functions with the same names and different prototypes. Because of that, all the libraries cannot be combined into a single static library so client and server parts have to be maintained separately.

B. Dlopen Abscence

As mentioned above, executables cannot be loaded dynamically. Due to this, the dlopen function family is not supported. In order to be flexible Xorg uses a module system, that heavily relies on this API because it is used during module loading and devices initialization. Every loaded module must define a global variable called <modulename>ModuleData, which contains version, setup and teardown functions. This object would be searched during the startup of the X server to fill ModuleDesc structure and register module.

However, these steps can be done with a minor alteration of source code even without dlopen. Functions inside the loader component must be stubbed. In every loadable module, which will be used later, special function must be implemented. It will allocate required function tables and ModuleDesc structure, perform registering and call module setup. This function must be called during DDX initialization instead of normal routine.

Despite the simplicity, this approach restricts available drivers. On the other hand, considering Baget usage as an embedded system, the target platform and list of devices are known during compilation. Due to this, it is not reasonable to use dynamic drivers.

C. Device Drivers

Device drivers in Xorg are part of modules. A module can contains one or multiple drivers at once. Module responsibilities are registration of itself and it's drivers. While module initialization and driver initialization are called once, device can be turned on or turned off multiple times. Input devices are monitored by server, so when Xorg detects an event on device file descriptor (i.e. poll reports that descriptor state is changed or SIGIO raises), driver is called to proceed input. It is expected that driver would generate an event that will be further processed by X server.

An example of action sequence for mouse driver *xorg-xf86-input-mouse*:

1) Mouse movement generates I/O on mouse file descriptor.
2) Xorg server detects I/O and calls driver function *MouseReadInput*.
3) Driver reads data from desctiptor and proceed it accoring to protocol and other settings.
4) Depending on data, driver calls xf86PostMotionEvent or xf86PostButtonEvent.
5) Xorg constructs and put events (for example, single MotionEvent) in server queue.

Modern DDX part of X.org uses a special interface to handle input drivers called udev [16], which is a Linux kernel device manager. However, old mouse and keyboards modules is still supported. Due to this, previous drivers *xorg-xf86-input-keyboard* and *xorg-xf86-input-mouse* were used as base due to it's simple requirements. Keyboard driver relies on input from stdin. Mouse driver expects a device file from which mouse packets data can be read. On top of that OS must provide either select, poll or SIGIO API to watch file descriptors for both drivers.

For output drivers, implementing standard screen functions is enough to use graphics with software rendering done by X. However, this driver heavily depends on the hardware platform and therefore will not be discussed in this article.

D. Xkbcomp Utility

When the key is pressed keyboard driver delivers scancode to the X server. In order to handle different types of keyboards and language sets, there must be a mapping between scancodes and actual symbols. To compile keymaps for current keyboard X server uses utility named xkbcomp [17]. During Xorg's initialization, the main process forks, redirects streams and executes this program. Xkbcomp is separated from the X server because it relies on client-side libraries, thus cannot be compiled into the server due to conflicting functions. But Baget does not support fork and exec API because processes are pre-defined.

It is possible to solve this problem in several ways.

Firstly, it can be achieved with rewriting xkbcomp utility with X server libraries instead of client ones. However, some parts of the code will be heavily altered and it will be hard to update it with new versions later.

Secondly, we can imitate fork by creating another process that manages xkbcomp during system startup. Communication and synchronization between different sides will be done with two FIFO's instead of streams redirection. There are some disadvantages of this approach. Some kind of protocol must be implemented to pass arguments to xkbcomp. Moreover, FIFO is visible to other processes that can write or read these files. On top of that additional process and FIFO files create unnecessary complexity and reduces clarity for users.

Although X server and X client cannot be simply linked into one executable, some tricks with GNU utilities ld and objcopy may help to get around this problem.

- Compile xkbcomp without running linker with gcc flag *-c*.
- Create relocatable output file with ld option *-r* from xkbcomp and X client libraries.
- Using objcopy flag *-G enter_func* create same file with all symbols hidden except *enter_func*.

After these steps, it is possible to link xkbcomp into the Xorg server process because all conflicting symbols are not visible after objcopy. After that, we can run xkbcomp from entry function *enter_func* directly or create a special thread for that purpose. Also, it is possible to get rid of FIFO by using unnamed pipes or memory since it is the same process now. Unlike the first solution, the required changes to source code are tiny. The main disadvantage of this approach is almost doubling X server executable size from 23MB to 40MB due to copying a lot of binary code from X client object files.

E. Local Sockets

X.org normally creates a UNIX socket to handle all incoming local requests. POSIX implementation of *socket* in Baget only supports AF_INET domain, therefore creation of UNIX domain socket is impossible. However, all requests can proceed if the client and server will consider using localhost instead of a socket file. This is possible to achieve by changing communication callbacks for local connections in header files.

F. User ID and Group ID

The majority of embedded devices are not supposed to be directly (e.g. terminal access) used. Because of this, Baget does not have a user identifier (UID) or group identifier (GID). But X.org have a lot of checks related to UID. The simplest solution is either stubbing UID functions to return 0, which is equal to root UID in UNIX, or ignoring all checks.

G. Server and Applications Resources

In order to use X.org without Filesystem Hierarchy Standard [18] a user must provide path to fonts, log files, configuration files, and other resources. This can be done during compilation.

Moreover, some applications are using libXt API [19] to draw interfaces. This may cause unclear behavior because libXt will look for app-defaults folder to find resources related to running program. In case of its absence, no warning will be generated, but the colors and shapes of drawn objects will be incorrect. It is possible to solve this problem by modifying libXt source code or setting environmental variable XAPPLRESDIR.

H. Launching Statically Compiled X.org and Applications

Some tweaks must be done to successfully launch X.org after static compilation.

First of all, to correctly call the renamed entry function of X.org, *argc* and *argv* should be carefully generated and provided. Arguments must include display number at least, for example, *:0*. Before running any X application environmental variable *DISPLAY* needs to be set accordingly.

Nowadays X.org will not display cursor and use mouse driver until desktop environment, which is mostly not required for an embedded system, is loaded. However, while launched in retro mode (with argument *-retro*), X.org will provide a working cursor and mouse.

I. XFree86 Issues

Since X.org was forked from XFree86, all issues discussed before is the same for both windowing managers with two exceptions. Firstly, dlopen is not mandatory for XFree86 - modules can be statically linked by default. Secondly, xkbcomp is not required to obtain a keyboard configuration. As for device drivers, its API has not changed much since then.

IV. Performance Comparison Results between XFree86 and Xorg and Evaluation

A tool named x11perf [20] was used to measure performance difference. x11perf tests server by calling X protocol commands multiple times and recording the number of operations per second. Both xFree86 and Xorg were installed on a test stand with the following characteristics: single-core MIPS 400mhz CPU and 4GB 400mhz RAM.

x11perf results include over 350 different tests. However, it may be combined into groups. For example, "Copy 10x10 from window to window", "Copy 100x100 from window to window", "Copy 100x100 from window to pixmap" will belong to the copy group.

Fig. 1 and 2 represent performance ratio of Xorg to XFree86 in different test groups. All values are normalized to the XFree86 result taken as 100%. For example, "Copy 500x500 from pixmap to pixmap" result is 194 and 271 operations per second for xFree86 and Xorg, respectively. That means the dot will be at 140% since Xorg result is 140% of xFree86. Each dot on the plot represents performance change for a particular test. Test names are omitted. The dotted line represents the mean value of a group. For this plots' data, please refer to Table 1 and Table 2.

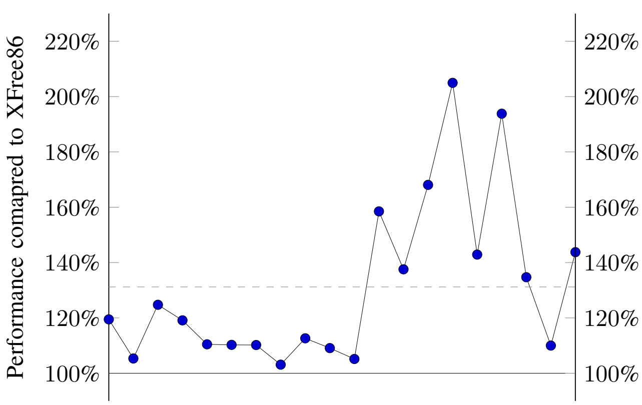

Fig. 1. x11perf Char Group Tests

Due to X.org's increase in complexity compared with XFree86, some operations may fall behind, for example, X protocol NoOperation call declined from 1070000 to 543000 per second. Despite that, a lot of test suits show better results, such as groups of char and copy operations, +30% and +10% respectively. Overall performance increase is 46%. Although most of it comes from tests utilizing windows operations, such as creating, moving, mapping and resizing.

TABLE I. x11perf Char Group Tests Data

Test name	Performance compared to XFree86 (%)
Char in 80-char line (6x13)	119,4779
Char in 70-char line (8x13)	105,336
Char in 60-char line (9x15)	124,7475
Char16 in 40-char line (k14)	119,1176
Char16 in 23-char line (k24)	110,4551
Char16 in 7/14/7 line (k14, k24)	110,2564
Char in 80-char image line (6x13)	110,2041
Char in 70-char image line (8x13)	103,1008
Char in 60-char image line (9x15)	112,6263
Char16 in 40-char image line (k14)	109,0909
Char16 in 23-char image line (k24)	105,157
Char in 80-char aa line (Charter 10)	158,5086
Char in 30-char aa line (Charter 24)	137,5635
Char in 80-char aa line (Courier 12)	168,0851
Char in 80-char a line (Charter 10)	204,9587
Char in 30-char a line (Charter 24)	142,8894
Char in 80-char a line (Courier 12)	193,8053
Char in 80-char rgb line (Charter 10)	134,7044
Char in 30-char rgb line (Charter 24)	110
Char in 80-char rgb line (Courier 12)	143,7653

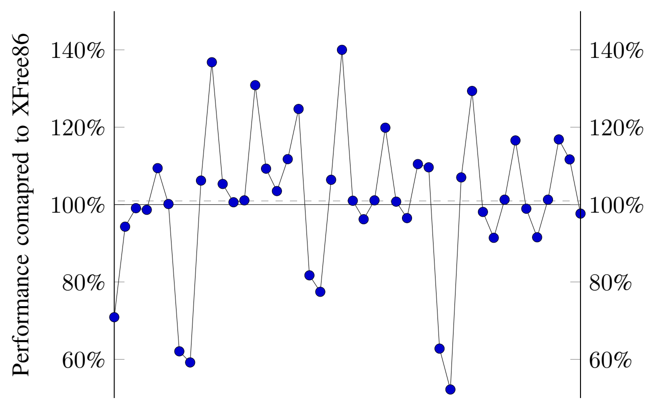

Fig. 2. x11perf Rectangle Group Tests

As for memory usage, while X.org consumes 3 MB RAM in idle state, while XFree86 uses only 1 MB.

V. Conclusions

X Windows System (specifically X.org v1.20.3) was successfully ported to Baget operating system. Porting X to non-POSIX systems may be unreasonable due to the usage of signals, file descriptors, polls, and other specific API. As for POSIX-compliant systems, one must implement device drivers and solve platform-specific issues. Covered in this article topics and methods can be used to adapt X to various systems with similar to Baget properties.

Two X implementations, Xorg and XFree86, were compared. Although XFree86 is older than the newest X.org release, it is easier to port. Another advantage is lower system requirements, for example, memory usage, which can be decisive for embedded systems. Xorg's superiority in performance may be spoiled in case of heavy usage of simple operations and program preference to draw small objects rather than big. As an example, a lot of either old or simple software such as standard utilities, calculators, notepads, etc. directly use such

TABLE II. X11 PERF RECTANGLE GROUP TESTS DATA

Test name	Performance compared to XFree86 (%)
1x1 rectangle	58,9443
10x10 rectangle	93,9502
100x100 rectangle	99,0637
500x500 rectangle	98,6301
1x1 stippled rectangle (8x8 stipple)	109,4218
10x10 stippled rectangle (8x8 stipple)	100,1506
100x100 stippled rectangle (8x8 stipple)	38,9021
500x500 stippled rectangle (8x8 stipple)	31,085
1x1 opaque stippled rectangle (8x8 stipple)	106,2124
10x10 opaque stippled rectangle (8x8 stipple)	136,7975
100x100 opaque stippled rectangle (8x8 stipple)	105,3333
500x500 opaque stippled rectangle (8x8 stipple)	100,6036
1x1 tiled rectangle (4x4 tile)	101,0929
10x10 tiled rectangle (4x4 tile)	130,8725
100x100 tiled rectangle (4x4 tile)	109,2896
500x500 tiled rectangle (4x4 tile)	103,5
1x1 stippled rectangle (17x15 stipple)	111,7521
10x10 stippled rectangle (17x15 stipple)	124,7163
100x100 stippled rectangle (17x15 stipple)	77,6224
500x500 stippled rectangle (17x15 stipple)	70,8904
1x1 opaque stippled rectangle (17x15 stipple)	106,4128
10x10 opaque stippled rectangle (17x15 stipple)	140
100x100 opaque stippled rectangle (17x15 stipple)	100,9967
500x500 opaque stippled rectangle (17x15 stipple)	96,063
1x1 tiled rectangle (17x15 tile)	101,0929
10x10 tiled rectangle (17x15 tile)	119,8758
100x100 tiled rectangle (17x15 tile)	100,7634
500x500 tiled rectangle (17x15 tile)	96,3855
1x1 stippled rectangle (161x145 stipple)	110,4701
10x10 stippled rectangle (161x145 stipple)	109,6311
100x100 stippled rectangle (161x145 stipple)	40,6897
500x500 stippled rectangle (161x145 stipple)	8,4746
1x1 opaque stippled rectangle (161x145 stipple)	107,0281
10x10 opaque stippled rectangle (161x145 stipple)	129,3706
100x100 opaque stippled rectangle (161x145 stipple)	98,0663
500x500 opaque stippled rectangle (161x145 stipple)	90,604
1x1 tiled rectangle (161x145 tile)	101,2774
10x10 tiled rectangle (161x145 tile)	116,5803
100x100 tiled rectangle (161x145 tile)	98,927
500x500 tiled rectangle (161x145 tile)	90,7692
1x1 tiled rectangle (216x208 tile)	101,2774
10x10 tiled rectangle (216x208 tile)	116,8421
100x100 tiled rectangle (216x208 tile)	111,6773
500x500 tiled rectangle (216x208 tile)	97,619

X API. On the other hand, modern frameworks, such as Qt and GTK, prefer to internally draw windows and use XPutImage call, which favors Xorg. Speaking in terms of functionality, XFree86 seriously falls behind due to a lack of modern X extensions.

There are some options for the future development of this research. First of all, since we adopted existing DDX for Xorg, we need to test graphic output very carefully and check if our changes do not break anything. Although we ran several programs such as x11perf and more complicated examples as browser and office suite, this validation process may be deceiving. We need to use existing or invent a new method to ensure correctness. Secondly, there are a lot of frameworks built upon X, such as Qt and GTK. Supporting them will be a benefit in terms of versatility because nowadays a lot of programs do not directly use X API but these frameworks. As was mentioned in the introduction - some inner parts or ideas of X evolved into the new interfaces. Adopting one of them, named KMS, may be very useful. Currently, it is the main backend for X server instead of fbdev that we used. Moreover, new technologies, such as Wayland, use it too. KMS API will allow us to ensure compatibility of Baget graphic subsystem with the upcoming changes and ease future development. Also only display features of X Window System are used, accelleration via 2D or 3D accellerators is not used. In the future, we plan to adapt DRI framework in the X server for Baget operating system in order to use GPU accellerated 3D applications.

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Developing Web-based Support Systems for Predicting Poor-performing Students using Educational Data Mining Techniques

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***Abstract*—The primary goal of educational systems is to enrich the quality of education by maximizing the best results and minimizing the failure rate of poor-performing students. Early predicting student performance has become a challenging task for the improvement and development of academic performance. Educational data mining is an effective discipline of data mining concerned with information integrated into the education domain. The study is of this work is to propose techniques in educational data mining and integrate it into a web-based system for predicting poor-performing students. A comparative study of prediction models was conducted. Subsequently, high performing models were developed to get higher performance. The hybrid random forest named Hybrid RF produces the most successful classification. For the context of intervention and improving the learning outcomes, a novel feature selection method named MICHI, which is the combination of mutual information and chi-square algorithms based on the ranked feature scores is introduced to select a dominant set and improve performance of prediction models. By using the proposed techniques of educational data mining, and academic performance prediction system is subsequently developed for educational stockholders to get an early prediction of student learning outcomes for timely intervention. Experimental results and evaluation surveys report the effectiveness and usefulness of the developed academic prediction system. The system is used to help educational stakeholders for intervening and improving student performance.**

***Keywords*—Academic performance prediction systems; educational data mining; dominant factors; feature selection methods; prediction models; student performance**

I. Introduction

Education is considered as a key factor for the development and long-term economic growth of every country. The poor performance causes the problem of under education and shortage of skilled manpower in developing countries. That is academic performance is an important and challenging task in educational institutions. In recent years, educational institutions have tried to improve academic performance and enrich the quality of their learning process. One of the main goals in educational systems is to achieve the high performance of education to increase the best results and decrease the failure rate of poor-performing students. Due to their poor performance, it has arrived at the worrying issue in educational institutions that those students are highly possible to fail, drop out, or repeat classes [1]. To solve this problem, the prediction has recently become one of the first and foremost effective methods since at-risk students can only be accurately identified early enough through the performance of prediction [2]. Therefore, the early prediction has been considered to be a powerful method for early identification of students who are at risk and need intervention and assistance.

In the recent decade, innovation and information technology have proven its significance in many areas of applications. Educational data mining (EDM) is a research field concerned with the application of data mining, machine learning, and statistics applied to explore data in educational contexts [3]. EDM combines several interdisciplinary fields of study such as machine learning, statistics, data mining, information retrieval, psycho-pedagogy, cognitive psychology, recommender system methods, and techniques to various educational datasets to resolve educational issues [4]. In the context of educational settings, various managerial settings, planning, and scheduling required effective techniques of EDM to uncover the knowledge and information of student learning patterns to give intervention and set up a policy to improve academic performance [5][6]. Various analysis techniques have been introduced for monitoring and anticipating academic performance to keep track of teaching, learning actions, and productive results.

The EDM process comprises of five main steps, as illustrated in Fig. 1. The first step is to get the targeted data, which can be collected from school databases or surveys using questionnaires. The collected raw data is never cleaned or it may be in the undesired format, so the second step is preprocessing step where data is cleaned and transformed into an executable format. The third step is to introduce particular techniques of EDM to obtain the target of the experiment. The answers to educational questions and decision making are obtained from the interpretation of experimental results. The last step is to modify the education process accordingly or defer this step until the next investigation is conducted for a better or more accurate result. The main goal of EDM is to extract information from educational data to address important educational questions and support decision making. Several studies on academic performance have been carried out using methods from the EDM discipline. Numerous tools have been applied according to the objectives of the studies. The distinction of characteristics of data, the complexity of data, the level of contribution signification, and limited performance of existing methods require advanced techniques of EDM [5][8].

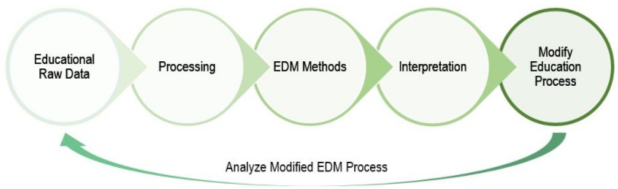

Fig. 1. Outline of EDM Process (Adapted from [7]).

Most researchers have worked on evaluating performances of students in higher education, yet the study on high school student performance evaluation is less. High school student performance is a significant indicator of developing the academic sector since it concerns the background knowledge of students for secondary education and higher education. To improve the poor performance of students in high schools, the right intervention and improvement must be made to low-performing students who are considered in the risk of failure. Poor performing students are highly possible to fail in the national exam and find themselves harder to survive in university life [9]. In the context of academic poor performance, EDM is used for timely prediction for intervention and improvement. In this study, we proposed developed models of EDM and integrate the model into a web-based system for predicting high school student performance.

In short, the modeling in this study is driven as the following research questions:

(i) Question 1: How to obtain dominant factors (highly influencing factors) that are required and sufficient for controlling student's outcomes?

(ii) Question 2: Which prediction model of EDM offers superior predictive results of student learning outcomes?

(iii) Question 3: How educators and related individuals can predict student learning outcomes (the prediction system) for giving intervention and improvement of student performance?

II. Literature Review

A. Feature Selection Methods and Prediction Models in EDM

Estrera et al. [10] predicted student performance for academic ranking in a university in the Philippine using the information records from high schools. Three prediction models of data mining were used in this prediction. The models used in the analysis are decision tree (DT), naïve Bayes (NB), and k-nearest neighbor (KNN). The data used in the prediction was obtained from the information provided by the admitted students to a university using a survey questionnaire conducted on them. To get a better prediction and better understanding of learning behaviors for assessment of students' success, the authors proposed feature selection methods: Chi-square (CHI), information gain (IG), and gain ratio (GR) in this study. As a result, the DT algorithm generates the highest accuracy of 90.67%.

Dimic et al. [11] studied the behavior patterns of students in the blended learning environment. Dataset used in the study was created by integrating data from multiple sources into a form applicable for data mining technique application. Dataset of 225 instances was obtained. The experiment has focused on data preprocessing steps in data mining. Feature selection methods such as Information gain (IG), Symmetrical uncertainty (SU), Relief (REF), correlation-based feature selection (CB), wrapper method, classifier subset evaluator methods were used to extract the most important features. The dependencies of features were computed using information measure (MI). The prediction models: naïve Bayes (NB), aggregating one-dependence estimators (AODE), decision tree (DT) and support vector machines (SVM) were used as prediction models using different feature subsets from each feature selection method. The results indicated that the REF, wrapper method, and MI acted as the most successful features selection methods in selecting the optimal feature sets. The presented research concluded that selecting the subsets of lower cardinality of students' learning activities gives a significant improvement in predictive accuracy in a blended learning environment.

Zaffar and Savita [12] investigated the analysis of feature selection methods in improving the performance of prediction models for predicting student academic performance. The study utilized six feature selection methods: correlation feature selection (CFS), Chi-squared, Filtered, information gain (IG), principal component (PC), and Relief. Fifteen classifiers were used: Bayesian Network (BN), naïve Bayes (NB), Naïve Bayes Updateable (NBU), Multilayer Perceptron (MLP), Simple Logistic (SL), Sequential Minimal Optimization (SMO), Decision Table (DT), OneR, PART, JRip, Decision Stump (DS), J48, Random Forest (RF), Random Tree (RT), and REP Tree (RepT). The experiments indicated that there is a significant improvement of 10 to 20% accuracy when using different feature selection sets.

Saa et al. [13] used information systems record as features that contain their high school records, and the university records to predict the student performance in higher education. The dataset used in the study was collected from a private university. The dataset consists of 34 features and 56,000 samples contained students' personal information. He introduced decision tree (DT), artificial neural network (ANN), random forest (RF), naïve Bayes (NB), logistic regression (LR), and generalized linear model (GLM) as prediction models. The study was to use student information record systems to predict the performance levels of students and identify the weakness and factors that affect student learning outcomes. Hence, information gain (IG) was used for selecting highly influencing factors. The experimental results suggested that the RF algorithm was the most appropriate prediction model in the prediction problem and the important factors affecting student performance were identified.

B. Early Prediction System using EDM

Early prediction or warning systems for predicting student performance is regarded as the improvement or next step in academic performance. It is referred to as prediction methods capable of discovering important and useful information about student learning patterns and risks of students such as retention, drop-out, and students' outcomes in an early stage. The purpose of using an educational early warning system is to give an earlier prediction of academic performance using features that influence students' success. Performance exhibited by students in their learning could be predicted in advance and possible failure can be prevented by the timely intervention [1].

Hu et al. [14] investigated students' interaction data in an online undergraduate course by using EDM techniques to develop an academic prediction system that could predict the students' learning outcomes exhibited by students in the course recorded in a learning management system (LMS). Various prediction models were used to predict the performance of the pass/fail of students. The optimal classification algorithm in the prediction system is the Classification and Regression Tree (CART) supplemented by AdaBoost. The experiment produced a classification accuracy of 90%. The study concluded that the early warning prediction system successfully predicted students' learning performance in an online course.

Akcapina et al. [15] proposed learning analytics to develop an early warning system for predicting at-risk students registered in an online course in a university. The study was carried out using a dataset of 76 second-year students registered in the Computer Hardw Course. The prediction model used in the system is a k-nearest neighbor (KNN). The experiment was examined regarding data obtained in Week 3, 6, 9, 12, and 14 to predict if at the end of the term student will be unsuccessful or successful. In the data of the first 3 weeks, the prediction rate of predicting unsuccessful student is 74%, while in the week 14th, the prediction rate increased to an accuracy of 89%.

Lee and Chung [16] developed a dropout early warning system based on machine learning to improve the performance of dropout prediction. The study dealt with the problem with the class imbalance between non-dropout and dropout groups of students. The two baseline prediction models used in this early warning system are random forest (RF) and boosted decision tree (DT). The RF and boosted DT are combined with the synthetic minority oversampling technique (SMOTE). The data used in this study is 165715 records of high school students taken from the National Education Information System (NEIS) of South Korea. The combination of a boosted decision tree that combined with SMOTE produced the best results and improved the performance of the dropout early prediction system.

C. The Current Study

Even if there were some existing works have proposed early perdition systems using popular algorithms in EDM in higher education or online courses, but still, a lot of attention is needed to build an academic performance prediction system with the analysis and help of developed prediction methods in EDM to get high and superior classification results. This work proposes a study of developing an academic performance prediction system (APPS) to predict student performance in high schools. The study compost of the selection of informative data, a proposed feature selection method, developed EDM models, and a web-based support system (the APPS) for timely-intervention to poor-performing students. The framework of the study is illustrated in Fig. 2.

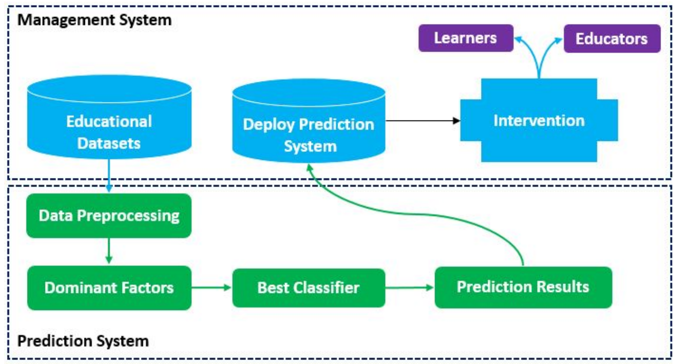

Fig. 2. The Framework of the Development of the APPS for Educational Settings.

III. Methodology

A. Participants and Data

To give intervention to high school students, informative data describing student learning patterns and highly influencing factors is required. However, in most developing countries, there is a shortage of educational data in high schools. Even if there exists, most of the existing data are only students' personal information which is not so useful for intervention purposes. Hence, this study carefully designs a questionnaire form concerning related important factors affecting student performance. The questionnaires for data collection were prepared with references, assistance, and guidance from (i) review literature, (ii) teachers from diverse educational institutions, (iii) staff from the department of research (MoEYS: Ministry of Education Youth and Sport, Cambodia), and (iv) senior researchers in the education field.

The target of the study is to improve the poor performance of students in high schools. The data used in this study was obtained from many high schools in Cambodia. Educators and related individuals can access a given online repository where survey questionnaires were designed and subsequently the survey for data collection can be conducted using Google document at any time they need. However, the time of conducting the survey is a critical factor. Oftentimes, the good time for intervention is before the final exam of the academic year. The data used in this study was collected by sharing questionnaires to high school students in the semester I. The reason is that this is a good time when the students already started their classes. They have managed the overall pictures of their learning habits, learning outcomes, and observed factors that have significant impacts on their learning outcomes during the semester. Collecting data in this period can help in predicting students' final grades and performance levels, so that the intervention can be implemented at the beginning of Semester II, especially before the final national exam. The questionnaire comprises 50 questions covering their personal information (6 questions), domestic factors (17 questions), students or individual factors (15 questions), school factors (14 questions), and score record (1 question) as shown in Table I. After students respond to the questionnaire, data can be collected and automatically stored in a repository where users can easily download the data with the right format and upload it in the prediction system to get prediction results. However, personal information is hidden since it contains some information that needs to be protected and some information that contains students' identity so that it cannot be used for intervention. The data used in the prediction consists of 43 predictors/features and one output variable. The output or target is the performing levels of students based on their score record.

B. Data Preprocessing

Data preprocessing is a boring but important phase that concern various data operations. Each operation aims to help EDM build a better predictive model. It is quite an important task to consider before putting into prediction. The proposed algorithms require data cleaning, data transformation, and data discretization to transform the data into an executable format and improve the performance of the models. The data preprocessing tasks and the experiment in our work were done using R Studio, an integrated development environment (IDE) for R programming language.

C. Evaluation Metrics

The classification performance is evaluated based on evaluation metrics of prediction tasks. We use two standard evaluation metrics to evaluate the performance of our proposed models. The two metrics are Accuracy (ACC) and Root Mean Square Error (RMSE).

TABLE I. FEATURES AFFECTING STUDENTS PERFORMANCE

Factors	ID	Predictors (number of questions)	Data types
		Personal information (6)	
Domestic	PEDU	Parents' educational levels (2)	Nominal
	POCC	Parents' occupational status (2)	Nominal
	PSES	Parents' socioeconomic levels (3)	Ordinal
	PI	Parents' involvement (4)	Ordinal
	PS	Parenting styles (4)	Ordinal
	DE	Domestic environment (2)	Ordinal
Student	SELD	Self-disciplines (5)	Ordinal
	SIM	Students' interest and motivation (4)	Ordinal
	ANXI	Students' anxiety toward their classes and exams (3)	Ordinal
	POSS	Students' possession materials (3)	Nominal
School	CENV	Class environment (1)	Ordinal
	CU	Curriculum (2)	Nominal
	TMP	Teaching methods and practices (4)	Ordinal
	TAC	Teachers' attribute & characteristics (4)	Ordinal
	RES	Academic resource (3)	Nominal

First, we want to compute the rate of our correct prediction. Hence, the first and foremost used metric in classification, called accuracy is used. From Table II, TP denoted the number of correct predictions, and E the denotes incorrect predictions. Accuracy of classification can be computed by using (1).

$$\mathrm{ACC} = \frac{\text{Correctly predicted values}}{\text{Total values}} = \frac{\sum \mathrm{TP_i}}{\sum \mathrm{TP_i} + \sum \mathrm{E_{ij}}} \tag{1}$$

TABLE II. CONFUSION MATRIX OF THE PREDICTION

		Predicted Classes			
		HR	***MR***	***LR***	***NR***
Actual Classes	***HR***	TP_1	E_{12}	E_{13}	E_{14}
	MR	E_{21}	TP_2	E_{23}	E_{24}
	LR	E_{31}	E_{32}	TP_3	E_{34}
	NR	E_{41}	E_{42}	E_{43}	TP_4

Our target is the predefined classes of student performance based on students' learning outcomes (scores). On the other hand, it is hard to predict their real ability or performance levels. Therefore, it is also important to measure how close our prediction to the true value. Hence, another metric, root mean squared error (RMSE) is proposed. The groups of poor-performing students are classified into four levels: high risk (HR), medium risk (MR), low risk (LR), and no risk (NR), which are represented by 1, 2, 3, and 4. Using a confusion matrix in Table II, RMSE can be calculated using (2).

$$\mathrm{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i^a - y_i^p)^2} \tag{2}$$

where $y^a \in \{1,2,3,4\}$ is the actual performance level and $y^p \in \{1,2,3,4\}$ is the predicted performance level. In contrast to the ACC, the smaller the RMSE, the better the model is.

D. Feature Selection Methods and Dominant Set

The performance of children, adult or adolescent can be affected by many influencing factors, especially external factors, motivation, and longitudinal factors. The main factor for students to be successful in their academic lives is not always about cleverness or IQ, but about discipline, motivation, and passion, which affect by environments around (themselves, parents, educators, and friends). The predictors are obtained for possibly effective factors that are categorized into three main factors: home or domestic factors, student or individual factors, and school factors [17]. As dimensionality of domain expands, the number of features affects student performance increases. However, it is not necessary to input all the features in the prediction system or not convenient to consider all factors for intervention. Hence, we wish to obtain the optimal set of factors with less dimension are needed and sufficient to control the success of students and improve the performance of classification models. We call that optimal set as the dominant set. Dominant factors play two important roles. First and foremost, determining dominant factors is used to enrich the quality of data, reduce computational costs, and improve prediction or classification performance. Secondly, the dominant factors describe the learning behaviors and factors that affect students' achievement and well monitor or assess the target in the academic system.

This study proposed feature selection methods to gain informative features. By gaining the informative features or dominant set, it can improve the performance of prediction models and use it as a recommendation to learn behaviors of students for intervention. Feature selection (FS) is a popular technique in data mining that is used to accomplish this purpose. There are three main approaches to feature selection, filter methods, wrapper methods, and embed/hybrid methods [18]. Wrapper and embed/hybrid methods are mostly computationally expensive to run for optimal feature subsets [19]. Filter-based selection methods are simple but effective in selecting important features and enhance the quality of prediction and classification performance. Filter feature selection is independent of classifiers and more scalable than wrapper methods [20]. We observe the performance of each feature selection method and selected the method that boosts the performance of classification accuracy. Three existing FS methods and a proposed FS method are studied and compared.

1) Information Gain (IG): IG is a commonly used feature selection method aiming at reducing dimensions of big data and improving the performance of prediction models [11][13]. IG measures the relevance of a feature by separating the training samples of input features to its target class. The algorithms use the concept of Shannon's entropy in information theory to rank the importance of input features [20].

2) Chi-square (CHI): CHI is a widely used algorithm especially for testing the independence of two discrete variables [10] & [12]. It is one of the famous variable tests in statistics and a popularly used feature selection method machine learning. The algorithm uses the concept of the chi-square score of the classes to get the rank list of all attributes [21].

3) Mutual Information (MI): MI is a method in the theory of information which is used to calculate or measure the dependency between random variables [22]. It is a symmetric measurement that can recognize non-linear relationships between variables. This property has made MI as a famous method for feature selection since other widely used criterion or method can only handle linear dependencies.

4) The Proposed FS Method (MICHI): Most of the filter feature selection algorithms such as information gain (IG), symmetric uncertainty (SU), and mutual information (MI) are mutual information-based methods [22][23]. These algorithms utilize the concept of mutual information (MI) and information theory. Chi-square is one of the robust feature selection methods that it is efficient for any dataset with categorical input features [21]. MI and CHI are the two popular and effective FS algorithms; however, we believe that the combined-FS algorithm is better than trusting on a single algorithm. The MICHI: MICHI is a proposed novel feature selection method which is the combination of CHI and MI algorithm based on the ranked feature scores.

In this study, we proposed a MICHI feature selection method as a combination of MI and CHI algorithms based on the ranked vector score. Since, different feature selection methods generate their feature score differently, before combining them, we first normalize the scores of both MI and CHI scores into the same format scale. The normalization can be done as in (3).

$$\overline{MI} = \frac{MI_i - MI_{min}}{MI_{max} - MI_{min}} \tag{3}$$

Similarly, the score of CHI can be normalized as in (4).

$$\overline{CHI} = \frac{CHI_i - CHI_{min}}{CHI_{max} - CHI_{min}} \tag{4}$$

Next, we can get the vector score of the MICHI algorithm which rearranges the order of importance of features base the combined scores as in (5).

$$MICHI = \begin{pmatrix} \overline{MI} \\ \overline{CHI} \end{pmatrix} \tag{5}$$

The score contains the information of both MI and CHI scores. Recall that to get the magnitude of a vector is given by the Euclidean norm of the vector. Hence, the score of the magnitude of the score vector can be computed using (6).

$$|MICHI_i| = \sqrt{\left(\overline{MI_i}\right)^2 + \left(\overline{CHI_i}\right)^2} \tag{6}$$

This means that the score of a feature in the MICHI algorithm can be computed as the norm of its score generated by the MI algorithm and score generated by the CHI algorithm.

E. Classification Algorithms

Several EDM techniques from many works of literature [2]- [13] were considered. We evaluated a diverse set of algorithms on a dataset to see what works and drop what does not work. This process is called spot-checking algorithms. Three classes of EDM techniques consist of statistical analysis techniques (predictive structural equation modeling), machine learning techniques (random forest, logistic regression, C5.0 of the decision tree, sequential minimal optimization, and multilayer perceptron), and a deep learning framework called deep belief network were executed and compared [24]. The random forest was found to be the best prediction model. The improvement of the previously proposed prediction models and additional models for predicting student performance was further carried out [25]. K-nearest neighbor (KNN), ensemble decision tree (Boosted C5.0 and Bagged CART), and random forest (RF) outperformed the rest prediction models. The developed prediction models are proposed in earlier works [26][27]. In this study, we use KNN, and three developed classifiers as our prediction models.

1) K-nearest neighbor (KNN): KNN is one of the effective non-parametric EDM models used for classification tasks. The KNN is an effective classifier and produces higher classification results [25]. Like many other classifiers, the k-NN classifier is noise-sensitive. Its accuracy highly depends on the quality of the training data. Noise and mislabeled data, as well as outliers and overlaps between data regions of different classes, lead to less accurate classification. It performs much better with the dominant set of important features.

2) Hybrid C5.0 and Hybrid RF: In the earlier work [26], we have proposed hybrid machine learning models which are the combination of baseline classifiers (support vector machine (SVM), naïve Bayes (NB), C5.0, and random forest (RF)) with principal component analysis (PCA) and validated by 10-fold cross-validation. The Hybrid C5.0 (C5.0+PCA+10-CV) and Hybrid RF (RF+PCA+10-CV) were found to be the best classifiers in our classification problem.

3) Improved Deep Belief Networks (IDBN): The IDBN is the optimization approach of deep belief network (DBN) model. We proposed an optimization approach composed of (i) feature selection method, (ii) optimization of hyper-parameter, and (ii) regularization method. The developed model has introduced in our earlier work [27]. The improved model was found to produce the most classification results when using larger datasets.

IV. Experimental Results of Prediction Models

A. Experimental Results

This section gives comparative results of the four proposed classifiers on the feature set of each FS method. Table III indicates the experimental results of the proposed classifiers with the original dataset. Table IV to Table VII shows the performance of the classifiers on subsets selected by IG, CHI, MI, and the proposed MICHI. The dominant set of each FS algorithm is found and the experimental results on each set are studied and compared.

Table III indicates the experiment results of the four classifiers with the original dataset concerning the two metrics: ACC and RMSE. The two tree-based models, Hybrid C5.0 and Hybrid RF generate the highest ACC and lowest RMSE.

The results presented in Table IV demonstrate the performance of the four classifiers using datasets from the IG feature selection method. The performance of Hybrid C5.0 and Hybrid RF are comparatively better than the other models. Hybrid RF generates the highest ACC and lowest RMSE with both selected sets and dominant sets.

From Table V, the performance of KNN is significantly improved when using the dominant sets containing the best 5 features set selected by the CHI algorithm. Hybrid C5.0 and Hybrid RF generated the most successful classification performance in this classification problem. The dominant sets improved the performance of both hybrid models.

The results of ACC and RMSE of the four classifiers using subsets from the MI algorithm are shown in Table VI. Hybrid C5.0 and Hybrid RF outperform the other models when using the selected set. However, the performance of KNN, Hybrid C5.0, and Hybrid RF are comparatively improved when considering the dominant sets.

Table VII demonstrates the performance of the proposed classifiers with the input feature subsets from the proposed MICHI algorithm. The performance is significantly improved when using the dominant sets. Hybrid RF produced the most successful classification result.

TABLE III. Results of Proposed Models on Original Datasets

Proposed Models	**KNN**	**Hybrid C5.0**	**Hybrid RF**	**IDBN**
ACC (%)	95.95	99.25	99.72	83.14
RMSE	0.261	0.073	0.041	0.759

TABLE IV. The Experimental Results using Subset from IG (29 Features)

Models	**Selected set**		**Dominant set**		
	ACC	***RMSE***	***N***	***ACC***	***RMSE***
KNN	95.34	0.257	5	97.34	0.153
Hybrid C5.0	99.85	0.040	29	99.85	0.040
Hybrid RF	99.87	0.038	29	99.87	0.038
IDBN	85.63	0.571	29	85.63	0.571

TABLE V. The Experimental Results using Subset from IG (29 Features)

Models	**Selected set**		**Dominant set**		
	ACC	***RMSE***	***N***	***ACC***	***RMSE***
KNN	95.34	0.257	5	99.17	0.087
Hybrid C5.0	99.85	0.040	29	99.86	0.026
Hybrid RF	99.87	0.038	29	99.95	0.015
IDBN	85.63	0.571	29	85.45	0.608

TABLE VI. The Experimental Results using Subset from MI (30 Features)

Models	**Selected set**		**Dominant set**		
	ACC	***RMSE***	***N***	***ACC***	***RMSE***
KNN	95.34	0.257	5	99.77	0.047
Hybrid C5.0	99.85	0.040	29	99.85	0.040
Hybrid RF	99.87	0.038	29	99.89	0.035
IDBN	85.63	0.571	29	87.03	0.525

TABLE VII. The Experimental Results using Subset from MICHI (29 Features)

Models	**Selected set**		**Dominant set**		
	ACC	***RMSE***	***N***	***ACC***	***RMSE***
KNN	95.34	0.257	5	99.85	0.011
Hybrid C5.0	99.85	0.040	29	99.89	0.035
Hybrid RF	99.95	0.011	*	99.98	0.008
IDBN	85.63	0.571	29	87.01	0.542

(*: from a set of five to 29 features, the values of ACC and RMSE are not statistically different)

B. Summary and Discussion

This study aims to obtain both an optimal prediction model and dominant set as useful information for educational stakeholders. The optimal method is combined with a dominant set to get accurate and informative results. Hybrid RF generates the highest ACC and the smallest RMSE. The result indicates that the proposed Hybrid RF with the dominant set selected by the MICHI algorithm performs the most successful classification result with an accuracy of 99.98% and RMSE of 0.008. Additionally, the experimental results indicate that the proposed feature selection method MICHI extracts the best dominant set. MICHI is a proposed novel feature selection method which is the combination of CHI and MI algorithms based on the ranked feature scores. The feature set selected by the MICHI algorithm is rank manually of the most important factors affecting student performance. The set does not only improve the performance of the prediction model but also describe the factors and student learning behaviors that require assistance and intention for improvement. Early predictions combined with counseling and intervention is known as an effective solution for improving the given problem. Therefore, the Hybrid RF model and the dominant set from the MICHI algorithm are combined and integrated into the APPS.

V. Design of the Apps

A. The Design of the APPS

This section presents the design of the APSS. The design consists of the web-based application linked to the server via the internet. The clients can assess the application and upload their data to obtain the results. The web-based application was created using Shiny (an open-source R package in R language). Since our experiment is done in R, hence Shiny App is the best choice. The shiny application is built using R language with its extension of the simplest code from HTML. CSS, and JavaScript. However, it is good that Shiny helps us to turn our analyses into interactive web applications without requiring HTML, CSS, or JavaScript knowledge.

The architecture of the academic prediction system is shown in Fig. 3. The recorded data that input in UI (user interface) is transferred to the server where the prediction model is executed to figure out what is the performance level of students. The results are then sent back to the client or user on the UI screen. The users are educational stakeholders such as teachers, administration office, or related individuals who have a dataset containing their student information. They can input the collected dataset and obtain the results. Fig. 4 presents the introduction of the system.

The prototype illustrated in Fig. 5 presents the operation follow of tasks in using the APPS. The flow chart aims to introduce to users how to use this system and the steps in using it to obtain the prediction results.

The system gives a link to an online repository for data collection by conducting a survey questionnaire designed using Google document so that users (educators, teachers, and schools) can decide when is the suitable time to make an early prediction for intervention. Once the data collection is done, users can upload the data in the system (*File Upload* button). The results of prediction will be released in the system; in which users can download the prediction results, identify the poor performing group of students for intervention, and other useful information for future use.

Fig. 6 demonstrates the information of students (the dominant factors) and the rank of highly influencing factors affecting student performance. The description of student data can be stored in the interface and viewed to understand students' information. The results of the prediction are shown in Fig. 7 where at the bottom, there is a button that users can download the prediction results as a dataset in CSV format for the use of any settings in the intervention.

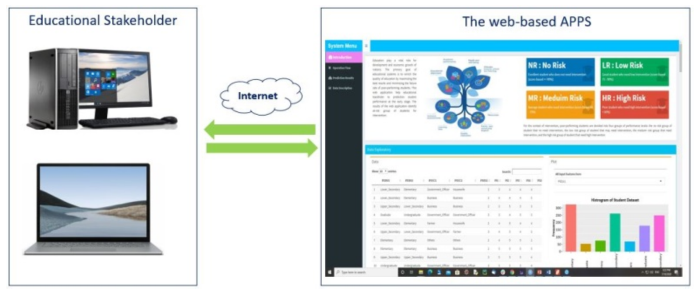

Fig. 3. Academic Performance Prediction System Architecture.

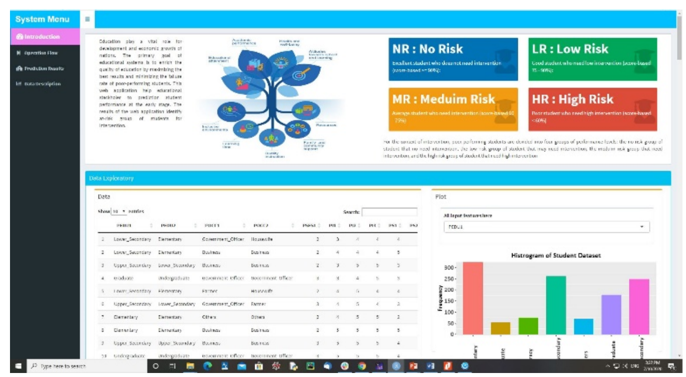

Fig. 4. A Prototype of the Introduce Interface of the APPS.

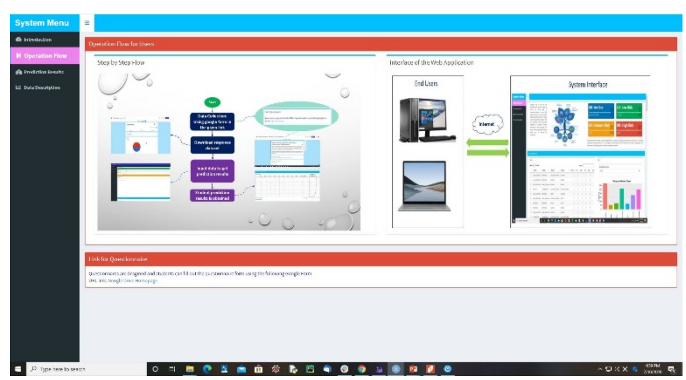

Fig. 5. Operation Flowchart to Instruct users of the Overall Process to Get Prediction Results.

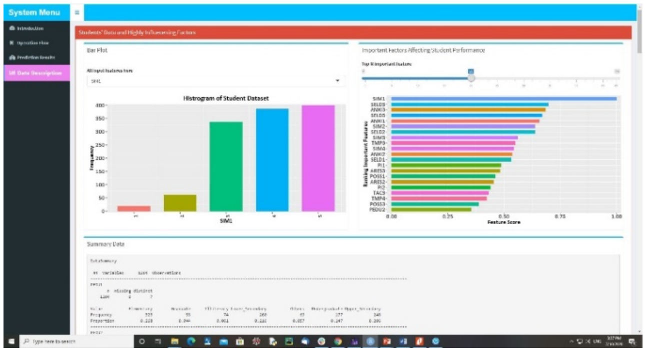

Fig. 6. Summary of the Dominant Factors and Ranking the Highly Influencing Factors.

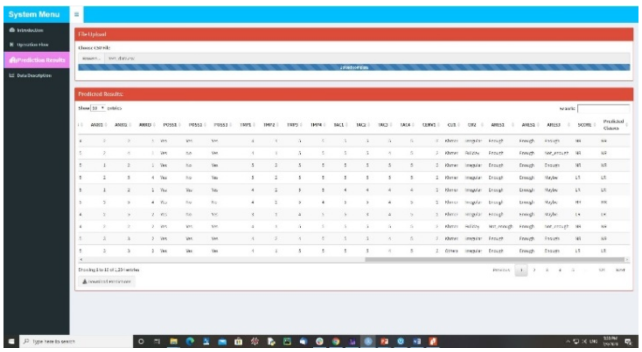

Fig. 7. Prediction Results Identifying the at-Risk Levels of Poor-Performing Students.

B. The System Deployment

Once the development of the Shiny app (the APPS) is done, it is shared or distributed with users. There is two basic option that can share. The first one is the Shiny app is shared as R scripts, users can use and edit from runGitHub. Users can use these scripts to launch the app from their R session. Users with no knowledge of programming or no care of how it works, the second type is the most comfortable way. Users can use the app from a web page or browser, which is from Shinyapps.io. This is definitely the most user-friendly way to share a Shiny app to users. They can navigate to our app through the internet with a web browser.

C. The System Evaluation

In evaluating the usability of the web application of the APPS, we designed a subjective questionnaire. The evaluation is carried out based on ten characteristics of the system: useful, motivating, user-friendly, relevant, reliable, efficient, organized, time cost, adaptable, and sophisticated. The questionnaire was designed with a 5-point Likert scale ranging from 1 to 5 (1: Strongly disagree, 2: Disagree, 3: Neutral, 4: Agree, 5: Strongly agree). The participant of 57 students and 10 teachers are invited to join the presentation and test the system. The response regarding the survey of usability of the web application is shown in Table VIII. When writing 11 (1) mean 11 students and 1 teacher agree with the given statement.

The student participants are 35 males and 22 female students, and teacher participants are 7 male teachers and 3 female teachers. Most students and teachers agreed that the system is useful and effective for predicting student performance and identify the poor performing student for intervention. The survey result shows that 82.08% supported that the system is useful (55.22% agree, 26.86% strongly agree), 83.58% thought that the system is motivating (62.68% agree, 20.89% strongly agree), 91.04% felt that the interface is friendly (82.08% agree, 8.95% strongly agree), 85.07% believed the information was relevant (58.20% agree, 14.92% strongly agree), and 73.13% thought that the system was reliable (62.68% agree, 20.89% strongly agree), 82.08% reported the efficient of the system (55.12% agree, 26.86% strongly agree), 74.62% claimed that the system was well-organized (58.78% agree, 20.89% strongly agree), 91.04% realized that the system speed (time cost) was fast (64.17% agree, 26.86% strongly agree), 88.05% of participants perceived that the system was adaptable (62.68% agree, 20.89% strongly agree), and 92.58% felt that the system was sophisticated (77.61% agree, 14.92% strongly agree). The analysis of the evaluation is shown in Fig. 8. The evaluation survey indicates the effectiveness and usefulness of the developed academic prediction system.

TABLE VIII. THE SURVEY RESULTS FOR EVALUATING THE APPS

Statement	**Description**	**5-point Likert Scale**				
		1	**2**	**2**	**4**	**5**
Useful	The system has helped student/instructor	0 (0)	0 (0)	11 (1)	31 (6)	15 (3)
Motivating	it is interesting to see that the system can give a feedback response for educators of the challenges the students face that affect their learning outcomes	0 (0)	0 (0)	12 (1)	37 (5)	10 (4)
User-friendly	The interface is easy to use	0 (0)	0 (0)	4 (2)	52 (3)	1 (5)
Relevant	It's easy to find the information I need	0 (0)	0 (0)	17 (3)	35 (5)	15 (2)
Reliable	I feel comfortable using the system	0 (0)	0 (0)	15 (3)	35 (4)	7 (3)
Efficient	It produces results immediately after feeding in the information, and results are given correctly, easily and fast.	0 (0)	0 (0)	11 (1)	31 (6)	15 (3)
Organized	It's easy to learn its use, the interface is simple and well structure.	0 (0)	0 (0)	14 (3)	31 (5)	12 (2)
Time cost	The data can be obtained anytime and fast with the questionnaire in Google form and results of prediction can obtain immediately after data collection	0 (0)	0 (0)	5 (1)	39 (4)	13 (5)
Adaptable	Student's weakness is known so that the right intervention can be put in place	0 (0)	0 (0)	6 (2)	44 (4)	7 (4)
Sophisticated	This is innovative technology in educational system	0 (0)	0 (0)	5 (0)	46 (6)	6 (4)

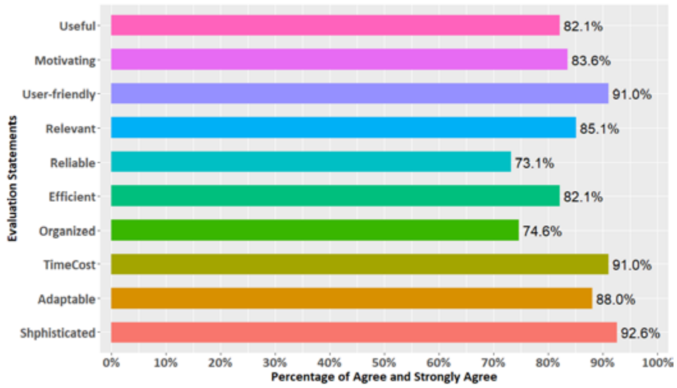

Fig. 8. User Feedback Rating the Characteristics of the APPS.

VI. Conclusion

The purpose of this study is to use EDM techniques to give an early-stage prediction for intervention and improving student performance based on a developed academic performance prediction system (APPS). The system gives faster and more comfortable ways of users to get in-time data of students for early predicting student performance levels and learning patterns and improving academic outcomes. The APPS composes of a developed prediction model and an effective feature selection method for determining the dominant factors for the success of student performance. We proposed a comparative study of EDM of prediction and classification task, the outperformed prediction models are then developed and optimized to get the most successful classification results. The comparative experiment of four classifiers (KNN and Hybrid C5.0, Hybrid RF, and IDBN) is carried out using feature sets from four FS methods (IG, CHI, MI, and the Proposed MICHI method). The analysis of dominant factors is cooperated and combined with the best classifier. The dominant set obtained from the MICHI algorithm significantly improves the performance of prediction models and used as a set of highly influencing factors that need to be considered for intervention and improvement of student performance. The experimental outcomes indicate that Hybrid RF outperformed the other three classifiers with the superior classification results. The developed prediction model and dominant factors are integrated into the web-based prediction system.

The finding of this work confirms the effectiveness of the prediction model and the usability of the APPS. The system illustrates operation flows consist of the method of faster and more comfortable way of data collection, dominant factors that have a significant impact on the student performance, and results of prediction. According to the results from APPS, it is informative for educational institutions to carry out the right intervention for improving student performance. The developed prediction system will help educational stakeholders such as teachers, educational administrators, and policymakers, and related individuals to improve academic performance in educational institutions. The teachers can quickly adjust their teaching methods and adopt adaptive teaching approaches to meet the needs of students. Educational stakeholders and related individuals can figure out the weak points and the solution to make improvements. Therefore, overall learning quality and learning performance can be improved greatly and reduce the failure rate of poor-performing students.

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Network Reconfiguration for Minimizing Power Loss by Moth Swarm Algorithm

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***Abstract*—This paper presents a network reconfiguration approach for minimizing power loss of the distribution system based on moth swarm algorithm (MSA). The MSA is a recent metaheuristic inspired from the navigational technique of moths in the dark for finding food sources. For searching optimal solution, MSA used three different mechanisms of generating new solutions consisting of Lévy-flights, Gaussian walks and spiral flight. The effectiveness of MSA is validated on two distribution systems consisting of the 33-nodes and 69-nodes. The simulation results are compared to particle swarm optimization and other available approaches in the literature. The calculated results on the test systems show that MSA can be an effective and reliable tool for the NR problems.**

Keywords*—*Network reconfiguration; moth swarm algorithm; power loss; particle swarm optimization; distribution system

I. Introduction

Network reconfiguration (NR) is a method of finding the optimal radial topology of the distribution system (DS) to reach the goals related to economic or technical benefits. It is performed by changing the status of switches located in the DS. Due to huge benefits of NR technique, it has attracted lot of concerns of researchers for finding the efficient solving method.

The first NR solving method is based on the branch-and-bound technique [1]. In which, to find the optimal network configuration for power loss reduction, each switch on closed network is opened to form the radial network reconfiguration. Then many different methods have been proposed for the NR problem, especially techniques based on metaheuristic algorithms. In [2],[3], genetic algorithm (GA) has been proposed to find the optimal network configuration for minimizing power loss of the DS. In which the branches and switches are encoded in the solution vector in [2] while in [3] only open switches are shown in the genetic string of GA. In [4], particle swarm optimization (PSO) is successful applied for the NR problem to find the optimal radial topology for power loss reduction. Similar to [4], PSO is also used as searching tool for finding network configuration in [5], [6]. The NR problem for loss reduction is also solved by artificial bee colony algorithm (ABC) [7]. In this study, the effectiveness of ABC has been demonstrated by the compared results with other approaches available in the literature. In [8], ant colony search (ACO) is used to determine the optimal network configuration to reduce losses and enhance load balancing of the DS. In addition to the aforementioned popular algorithms which have been successfully applied to the NR problem, some reconfiguration methods based on newly developed algorithms or improved versions of the well-known methods have also been proposed and achieved good results such as improved cuckoo search algorithm (ICSA) [9], fireworks algorithm (FWA) [10], biogeography based optimization (BBO) [11], modified particle swarm optimization (MPSO) [12], improved selective binary PSO (IS-BPSO) [13], modified flower pollination algorithm (MFPA) [14], invasive weed optimization (IWO) [15], adaptive shuffled frogs leaping algorithm (ASFLA) [16], binary particle swarm gravity search algorithm (BPSOGSA) [17], harmony search algorithm (HSA) [18], [19], improved adaptive imperialist competitive algorithm (IAICA) [20], and grey wolf optimization (GWO) [21].

It can be seen that the NR problem can satisfy various technical goals such as loss reduction, load balancing, feeder balancing, voltage improvement and reliability enhancing, etc. In particular, loss reduction is one of the most important goal in operating the distribution network because the power loss of the distribution network is often higher than the losses of other parts of the power system. In terms of the method of solving the NR problem, finding new approaches to enrich the search tools of optimal network configuration is still a worthy of concern as the development of the field of optimization is more powerful and more and more good algorithms have been born.

Moth swarm algorithm (MSA) is a recent metaheuristic inspired from the navigational technique of moths in the dark for finding food sources [22], [23]. The moths fly in the right direction in the dark based on light sources like stars or moons. To apply MSA for the optimization problem, position of a light source and its luminescence intensity are considered as a candidate solution and the quality of the candidate solution. Furthermore, the population of moths is divided into three groups consisting of pathfinders, prospectors and onlookers with different roles for exploring and exploiting the search space. In [22], MSA has shown advantages compared with PSO as well as other methods for the optimal power flow problem but the application of MSA for other problems related to power system like the NR problem is still a question.

In this study, MSA is adapted to find the optimal network configuration with minimizing power loss. The NR method based on MSA is evaluated on the 33-nodes and 69-nodes distribution networks. The calculated results are compared with PSO and other available approaches in the literature. The main contributions of the paper can be summarized as follows:

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- MSA is successful adapted to solve the NR problem for minimizing power loss.
- MSA is better than PSO for finding the optimal network configuration with higher successful rate and better quality of obtained solution.
- MSA is able to determine the better network configuration compared to some available approaches in the literature.

The structure of the paper is organized as follows: The mathematical formulation of the NR problem is presented in the Section 2 meanwhile the MSA for solving the NR problem is shown in Section 3. Section 4 presents the performance of MSA on the test systems. Finally, the conclusion is demonstrated.

II. Mathematical Formulation of Network Reconfiguration

The power loss ($Ploss$) of the distribution system (DS) is determined by sum of loss of lines in the DS as follows:

$$Ploss = \sum_{i=1}^{n_{li}} \Delta P_i \tag{1}$$

In which, ΔP_i is power loss of the line i. n_{li} is number of lines of the DS.

The network configuration obtained has to satisfy the below constraints:

Constraint of radial topology: This condition is maintained by the following formula [24]:

$$|det(M)| = 1 \tag{2}$$

In which, $det(M)$ is the M matrix's determinant. M is a line by node matrix that is built by relationship among lines and nodes of the DS.

Constraints of voltage and current:

$$\begin{cases} V_{lo} \le V_j \; ; j = 1, \dots, n_{no} \\ I_i \le I_{i,hi} \; ; i = 1, \dots, n_{li} \end{cases} \tag{3}$$

In which, V_j is the voltage magnitude of the node j. V_{lo} is the allowed minimum voltage magnitude that is usually chosen to 0.95 p.u. n_{no} is the number of nodes of the DS. I_i and $I_{i,hi}$ are the current and rated current of the line i.

III. Moth Swarm Algorithm for Network Reconfiguration

The moths transit through a space relying on the angle between a light source and their flying direction. Therefore, in MSA, position of each moth is also considered as a candidate solution. Furthermore, the population of moths is divided into three groups consisting of pathfinders, prospectors and onlookers. In which, the first group has a role of exploring the search space to determine light sources for guiding the warm. The second one has a role of hiking the area that is the neighborhood of the light sources. The final group tends to move slowly to the light source obtained by the second group.

The application of MSA for the NR problem is described in more details as following:

Step 1: Generate randomly new solutions

In order to apply MSA for the NR problem, each network configuration is considered as the position of moths in the search space. Thus, the population of solutions are produced randomly as follows:

$$Mo_{i,j} = round\left(Mo_{lo,j} + rd_1.\left(Mo_{hi,j} - Mo_{lo,j}\right)\right) \tag{4}$$

Where $Mo_{i,j}$ is the value of the variable j with j = 1, 2, … , d of the solution i with i = 1, 2, … , n. The d and n are dimension of the problem and size of population. rd_1 is result of the function of rand [0,1]. $Mo_{hi,j}$ and $Mo_{lo,j}$ are the upper and lower boundaries of the variable j.

The quality of each moth in the population is calculated by using the fitness function as follows:

$$f_i = Ploss + K_p.[(\max(V_{min} - V_{lo}), 0) + (\max(\max(I_i/I_{i,hi}) - 1), 0)] \tag{5}$$

Where K_p is penalty coefficient. V_{min} is the minimum voltage amplitude of the DS.

Based on the moths' quality, n_{pa} best moths are selected to become pathfinders or called light sources and the rest moths will be considered as prospectors and onlookers follow descending order of quality.

Step 2. Generate new solutions for updating pathfinders

All of pathfinders are updated in this step but not of all variables of each pathfinder is renewed. The variables chosen for updating by the following technique. Firstly, the variation coefficient of all variables in the dimension j of the pathfinders (cv_j) is determined as follows:

$$cv_j = \frac{\sqrt{\frac{1}{npa}\sum_{i=1}^{npa}\left(Mo_{i,j} - \frac{1}{npa}\sum_{i=1}^{npa} Mo_{i,j}\right)^2}}{\frac{1}{npa}\sum_{i=1}^{npa} Mo_{i,j}} \tag{6}$$

The average value of variation coefficients is calculated as below:

$$cv_{mean} = \frac{1}{d}\sum_{j=1}^{d} cv_j \tag{7}$$

Then any variable of pathfinder that has the lower variation coefficient compared to the average variation coefficient is selected for renewed. The group of variables (g_{up}) for renewing is determined as follows:

$$j \in g_{up} \; ; if \; cv_j < cv_{mean} \tag{8}$$

In order to update the variable that belongs to the group g_{up}, the crossover technique among pathfinders are used as follows:

$$Mo_{p,new} = round\left(Mo_{r1} + LV_{p1}.(Mo_{r2} - Mo_{r3}) + LV_{p2}.(Mo_{r4} - Mo_{r5})\right) \tag{9}$$

Where $Mo_{p,new}$ are new sub-solution vector of the pathfinder p with $p = 1, \dots, n_{pa}$. Mo_{r1} to Mo_{r5} are five pathfinders selected randomly. LV_{p1} and LV_{p2} are scale factors which are produced by the Lévy-flights as below:

$$LV_i = sc \otimes levy(\alpha) \quad (10)$$

Where sc is a scaling factor that is chosen to 0.01. α is distribution factor in [0, 2]. ⊗ is the entry-wise multiplications.

Then, the new sub-solution vector of the pathfinder is merged with the rest part of the pathfinder to create new pathfinder as follows:

$$Mo_{p,new,j} = \begin{cases} Mo_{p,new,j} \ ; \ if \ j \in \ g_{up} \\ Mo_{p,j} \quad\quad ; \ otherwise \end{cases} \quad (11)$$

The news pathfinders are evaluated quality by the fitness function. Then, the selection technique is used to retain the better pathfinder as follows:

$$Mo_{p,new} = \begin{cases} Mo_{p,new} \ ; \ if \ f(Mo_{p,new}) < \ f(Mo_p) \\ Mo_p \quad\quad ; \ otherwise \end{cases} \quad (12)$$

Step 3. Generate new prospectors

The number of prospectors (n_{pr}) in the population is not fixed, it depends on the number of iterations performed by the algorithm and is determined as follows:

$$n_{pr} = round\left((n - n_{pa}).\left(1 - \frac{g}{G}\right)\right) \quad (13)$$

Where g and G are the current iteration and the maximum number of iterations for performing MSA.

Then each prospector in the population is renewed based on the spiral flight technique as follows:

$$Mo_{i,new} = round\left(\left|Mo_i - Mo_p\right|.e^{\varphi}.cos2\pi\varphi + Mo_p\right) \quad (14)$$

Where, $Mo_{i,new}$ and Mo_i is the new and current solution i with $i \in \{n_{pa} + 1, \dots, n_{pa} + n_{pr}\}$. φ is a random number in $\left[\left(-1 - \frac{g}{G}\right), 1\right]$. Mo_p is a pathfinder selected from the n_{pa} of pathfinders. The probability of the pathfinder p chosen is determined as follows:

$$Prob_p = \frac{f_p}{\sum_{p=1}^{npa} f_p} \quad (15)$$

Based on the new prospectors generated, their quality is evaluated by the fitness function. However, in this step, the selection technique does not used to update the current prospectors because the new prospectors may be chosen to become light sources if they have better quality than the pathfinders. Thus, updating of the current population of moths will be performed at the end of the MSA.

Step 4. Generate new onlookers

In order to produce new onlookers, the number of onlookers that is determined by (16) is divided into small groups and each group is generated by different techniques. The details of producing new solutions of onlookers are described as follows.

$$n_{on} = n - n_{pa} - n_{pr} \quad (16)$$

A half of new onlookers are generated by using Gaussian walks technique as follows:

$$Mo_{i,new} = round\left(Mo_i + \gamma + (rd_2.Mo_{best} - rd_3.Mo_i)\right) \quad (17)$$

Where $Mo_{i,new}$ and Mo_i is the new and current onlooker i with $i = 1, \dots, n_{on}/2$. Mo_{best} is the best so far moth in the population. rd_2 and rd_3 are random number in [0,1]. γ is a normal stochastic distribution vector that is determined from the Gaussian walks technique as follows:

$$\gamma = rd_4 \otimes N\left(Mo_{best}, \frac{\log g}{g}.(Mo_i - Mo_{best})\right) \quad (18)$$

Where rd_4 is random number vector with length of d.

A rest half of new onlookers are generated by the associative learning technique as follows:

$$Mo_{i,new} = round\left(Mo_i + \tau.rand\left(\left[Mo_i - Mo_{i,lo}, Mo_{i,hi} - Mo_i\right]\right) + 2g/G.rd_5.(Mo_{best} - Mo_i) + (1 - g/G).rd_6.\left(Mo_p - Mo_i\right)\right) \quad (19)$$

Where $Mo_{i,new}$ and Mo_i is the new and current onlooker i with $i = 1, \dots, n_{on}/2$. τ is scale factor chosen to 0.001. Mo_p is a pathfinder selected from the n_{pa} of pathfinders with probability of $Prob_p$. $Mo_{i,lo}$ and $Mo_{i,hi}$ are lower and upper boundaries of the moth. rd_5 and rd_6 are random number in [0,1].

Based on the new onlookers generated, their quality is evaluated by the fitness function.

Step 5: Update new population and determine the best so far solution.

Based on the quality of the current population and new moths. The moths are sorted in ascending order of the fitness values. The n top moths are selected to become the new population and the types of moths are determined again. In addition, the best pathfinder of the population is chosen to the best so far solution.

The steps 2 to 5 of MSA are executed continuously until the number of iterations reach to the maximum value G. Then the best so far solution is considered as the result of the NR problem.

IV. Results and Discussion

In order to find optimal network configuration, the MSA for the NR problem is run in a personal computer with 2.4Gh of CPU and 4G of RAM on the Matlab platform. Two DS comprising of the 33-nodes and 69-nodes systems shown in Fig. 1 [25], [26] are used to find the best network configuration. For both of the DS, the penalty coefficient K_p in the fitness function equation is set to 1000. The population of moths are set to 20. The maximum number of iterations is chosen to 150. The MSA is executed in 50 trials, the best network configuration in all of runs are considered as the results of the problem. In this study, the results obtained by the proposed MSA are not only compared to those of previous methods in the literature, but also to the PSO that is coded and performed in the same computer for demonstrating the effectiveness of the MSA. In which, PSO is one of well-known algorithm and it is successful applied to many network reconfiguration problem [4],[5],[6].

A. The Optimal Network Reconfigurations

For the 33-nodes network, the initial network configuration with open switches {33-34-35-36-37} that causes power loss ($Ploss$), minimum voltage amplitude (V_{min}) and maximum of current per rate current $(I/I_{rate})_{max}$ of 202.6863 kW, 0.9131 p.u and 0.8250, respectively. In which, the V_{min} is 0.0369 lower the permit range of the voltage amplitude. The network reconfiguration result by using the proposed MSA is presented in Table I. After reconfiguration by MSA, the switches {7-14-9-32-28} are opened instead of {33-34-35-36-37}. At that time, the total loss of the system is only 139.9823 kW that is reduced by 30.94% compared to the original network configuration. Furthermore, the V_{min} and $(I/I_{rate})_{max}$ have been enhanced. In more details, the V_{min} is 0.0281 higher than that of the initial configuration and the $(I/I_{rate})_{max}$ is lightly reduced from 0.8250 to 0.8126 after reconfiguration. The voltage and current of the 33-nodes system before and after reconfiguration by MSA are shown in Fig. 2. The figures demonstrate that most of node voltage amplitudes have been improved compared to the initial network configuration and the current of lines has been reduced after reconfiguration.

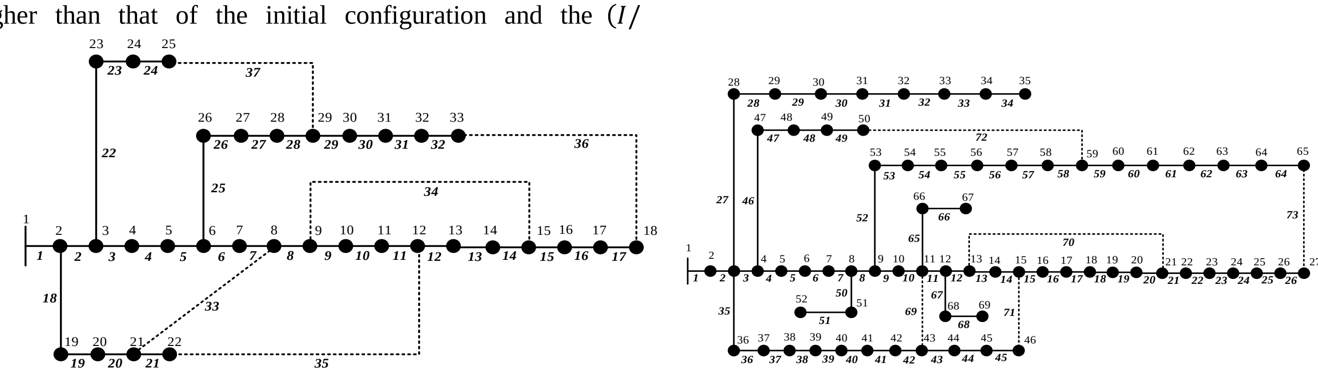
In comparisons with PSO and other previous methods, the result obtained by MSA is equal to that of PSO and the methods consisting of ACO [8], FWA [10]. While the methods comprising of IS-BPSO [13], ICSA [9], BBO [11], MPSO [12], MFPA [14], MOIWO [15], IAICA [20] and GA [3], the loss reduction obtained by MSA is 0.21% lower than that of the aforementioned methods but the minimum voltage amplitude is 0.0034 higher and violation of minimum voltage constraint at a smaller level than above methods. Compared to and HSA [18], the loss reduction obtained by MSA is 1.08% and 1.34% higher. In addition, the minimum voltage amplitude is also more improvement than the two above methods.

For the 69-nodes network, the $Ploss$, V_{min} and $(I/I_{rate})_{max}$ of the initial network configuration with open switches {69-70-71-72-73} are 224.8871 kW, 0.9092 and 0.8767, respectively. In which, the V_{min} is 0.0408 lower the permit range of the voltage amplitude. The network reconfiguration result by using the proposed MSA is presented in Table II. After reconfiguration by MSA, the switches {69-70-14-57-61} are opened. This network configuration only causes 98.5875 kW that is reduced by 56.16% compared to the original network configuration. In addition, the V_{min} and $(I/I_{rate})_{max}$ have been improved. In which, the V_{min} is 0.0403 higher than that of the initial configuration and the $(I/I_{rate})_{max}$ is lightly reduced from 0.8767 to 0.8572 after reconfiguration. The voltage and current of the 69-nodes system before and after reconfiguration by MSA are shown in Fig. 3. The figures send a message that the obtained benefits in enhancing voltage and current profiles after reconfiguration are noteworthy. Compared with PSO and other previous methods, the result obtained by MSA is identical to that of PSO and the methods consisting of ICSA [9] , ASFLA [16], BPSOGSA [17], FWA [10], BBO [11], GWO [21] and IAICA [20]. Compared to HSA [19], the loss reduction obtained by MSA is 2.93% higher.

B. The Performance of MSA

The performance of MSA and PSO for the 33-nodes and 69-nodes system in 50 independent runs as presented in Table III. For the 33-nodes system, although both MSA and PSO have identified the optimal solution, MSA has found the best solution in 29 runs while PSO has only reached in the 5 runs in total of 50 independent trials. In addition, the maximum, average and standard deviations (STD) values of the fitness function in 50 runs of MSA are also much smaller than those of PSO. Specifically, these values of MSA are 161.0744, 150.6089 and 2.7915 which are much lower than 185.3416, 161.6831 and 9.3295 of PSO. The average number of converged iterations of MSA is higher than that of PSO, but obviously MSA usually converges to the optimal value while PSO is not. The calculation time of MSA is 1.0894 seconds faster than PSO. The maximum, minimum and average convergence curves of MSA and PSO for the 33-nodes system are presented in Fig. 4(a). From the figure, the average curve of MSA converges to lower value than that of PSO and the convergence value of the MSA's average curve is nearly equal to the convergence value of the smallest curve. This proves the superior efficiency of MSA compared to PSO for the NR problem.

The results obtained on a 69-nodes system are similar to those of the 33-nodes system. In 50 runs, the number of runs found the best solution of MSA is 20 while this number of PSO is only 5 runs that is 15 runs lower than compared to MSA. Similarly, the maximum, average and STD values of the fitness function in 50 runs of MSA are also much smaller than those of PSO. The calculation time of MSA for the 69-nodes system is 3.2731 seconds faster than PSO. The convergence curves of MSA shown in Fig. 4(b) are also send a message that MSA is more efficient and reliable than PSO for the NR problem.



a) The 33-nodes test system b) The 69-nodes test system

Fig. 1. The Test 33-Nodes and 69-Nodes Systems.

TABLE I. THE RESULTS OF NETWORK RECONFIGURATION BY MSA FOR THE 33 NODES SYSTEM

Method	Open switches	Ploss (kW)	Reduction (%)	V_{min} (p.u)	$(I/I_{rate})_{max}$
Before rec.	33-34-35-36-37	202.6863	-	0.9131	0.8250
Proposed MSA	7-14-9-32-28	139.9823	30.94	0.9412	0.8126
PSO	7-14-9-32-28	139.9823	30.94	0.9412	0.8126
ACO [8]	7-14-9-32-28	139.9823	30.94	0.9412	-
FWA [10]	7-14-9-32-28	139.9823	30.94	0.9412	-
IS-BPSO[13]	7-14-9-32-37	139.5500	31.15	0.9378	-
ICSA [9]	7-14-9-32-37	139.5500	31.15	0.9378	0.8123
BBO [11]	7-14-9-32-37	139.5500	31.15	0.9378	-
MPSO[12]	7-14-9-32-37	139.5500	31.15	0.9378	-
MFPA [14]	7-14-9-32-37	139.5500	31.15	0.9378	-
IWO [15]	7-14-9-32-37	139.5500	31.15	0.9378	-
IAICA [20]	7-14-9-32-37	139.5500	31.15	0.9378	-
GA [3]	7-14-9-32-37	139.5500	31.15	0.9378	-
HSA [18]	7-10-14-36-37	142.6816	29.60	0.9377	-

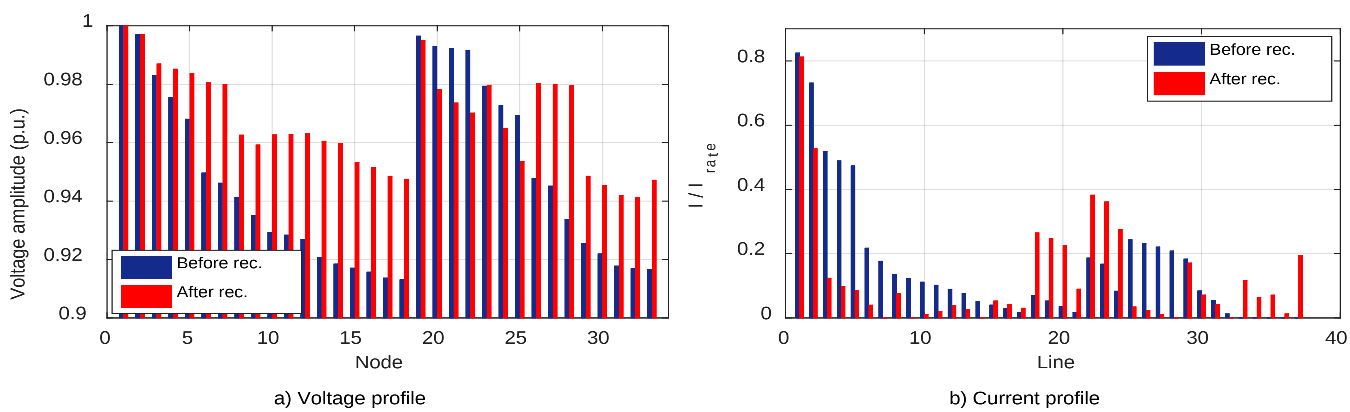


Fig. 2. Voltages and Currents of the 33-Nodes System before and after Reconfiguration.

TABLE II. THE RESULTS OF NETWORK RECONFIGURATION BY MSA FOR THE 69 NODES SYSTEM

Method	Open switches	Ploss (kW)	Reduction (%)	V_{min} (p.u)	$(I/I_{rate})_{max}$
Before rec.	69-70-71-72-73	224.8871	-	0.9092	0.8767
Proposed MSA	69-70-14-57-61	98.5875	56.16	0.9495	0.8572
PSO	69-70-14-57-61	98.5875	56.16	0.9495	0.8572
ICSA [9]	14-57-61-69-70	98.5875	56.16	0.9495	-
ASFLA [16]	69-70-14-56-61	98.5875	56.16	0.9495	-
BPSOGSA [17]	69-70-14-56-61	98.5875	56.16	0.9495	-
FWA [10]	69-70-14-56-61	98.5875	56.16	0.9495	-
BBO [11]	14-70-69-58-61	98.5875	56.16	0.9427	-
GWO [21]	56-14-61-69-70	98.5875	56.16	0.9495	-
IAICA [20]	69-70-14-56-61	98.5875	56.16	0.9495	-
HSA [19]	13-18-56-61-69	105.190	53.23	0.9495	-

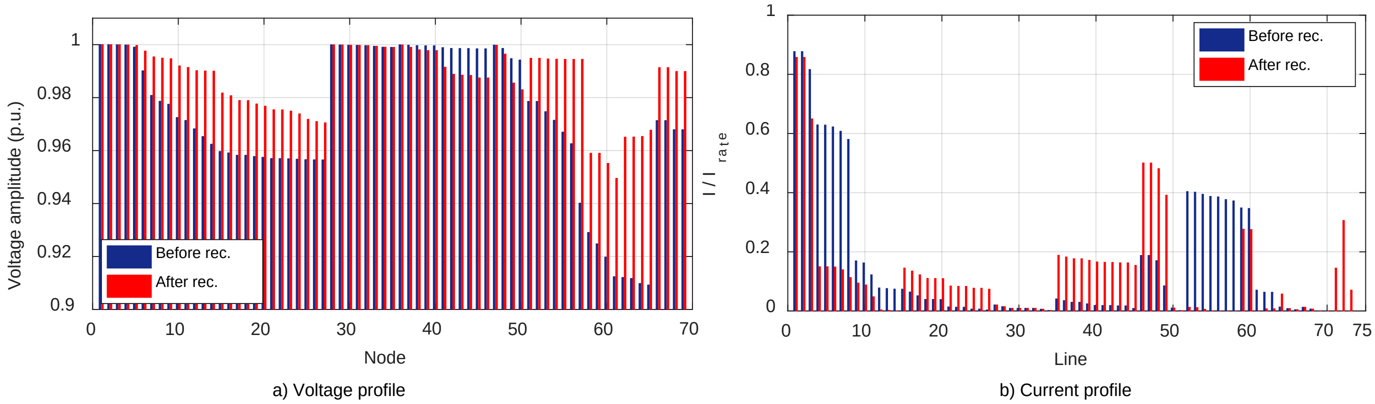


Fig. 3. Voltages and Currents of the 69-Nodes System before and after Reconfiguration.

TABLE III. THE PERFORMANCE OF THE PROPOSED MSA FOR TWO TEST SYSTEMS

Item	**MSA for the 33-nodes system**	**PSO for the 33-nodes system**	**MSA for the 69-nodes system**	**PSO for the 69-nodes system**
Optimal solution	7-14-9-32-28	7-14-9-32-28	69-70-14-57-61	69-70-14-57-61
Number of trials found the optimal solution	29/50	5/50	20/50	12/50
Maximum value of fitness function	161.0744	185.3416	116.3852	140.7413
Minimum value of fitness function	148.7392	148.7392	99.1169	99.1169
Average value of fitness function	150.6089	161.6831	105.0324	114.1333
STD value of fitness function	2.7915	9.3295	6.2900	15.1119
Maximum of convergence iterations	149	67	150	76
Minimum of convergence iterations	4	2	8	7
Average convergence iterations	63.06	22.84	79.06	35.18
STD of convergence iterations	48.3167	17.4313	50.1603	17.6412
Execution times (second)	8.3247	9.4141	25.2191	28.4922

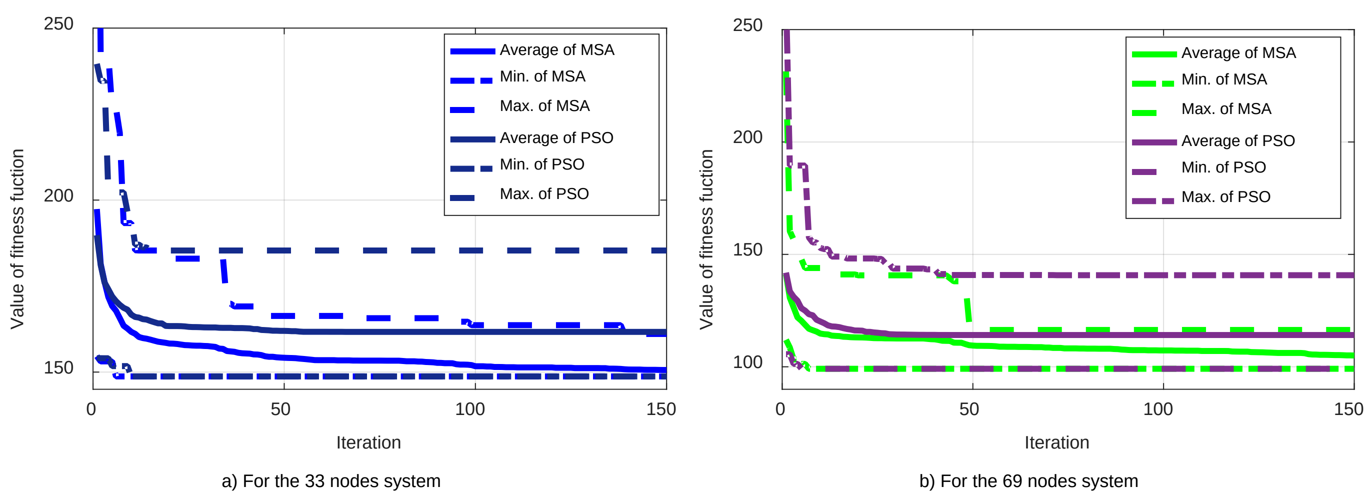


Fig. 4. Comparisons of Convergence Curves of MSA and PSO for Two Test Systems.

VI. Conclusion

The paper presents the network reconfiguration approach for the NR problem based on MSA. The goal of the NR problem is to find the best network configuration for minimizing power loss. The effectiveness of MSA is validated on two DS consisting of the 33-nodes and 69-nodes. The simulation results are compared to PSO and other available approaches in the literature. In comparison with PSO, MSA can determine the best network configuration with higher successful rate and better quality of obtained solution. In addition, MSA also outperforms to some previous approaches in the literature. Thus, MSA can be an effective and reliable tool for the NR problems. For future work, MSA can be used for the planning of practical distribution system operation.

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Reduction of the Humidity Contained in the Harvest Cereals by the Means of in High Frequency Electromagnetic Field Processing

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***Abstract*—The new environmental friendly microwave technologies represents an important concern in the environmental policies. The use of microwave energy for the processing of different agricultural products presents the advantage of a green technology which allow a uniform distribution of electromagnetic and thermal field with a short relatively time of the process. In the paper is studied the microwave drying technology used in the drying process of oat seeds. In this sense the experiments were carried out for different working conditions of the equipment with respect to applied microwave power and obtained temperatures. A numerical model associated to the problem and solved by the means of finite element method is used. These allows us to obtain the electromagnetic field distribution through simulation inside the microwave dryer. The simulations were performed in order to obtain good quality products that may be used for seeding and food industry. The approached method is flexible so as it can be applied to all cereals.**

Keywords—High frequency electromagnetic field; numerical simulation; microwave processing; oat drying; agricultural seeds

I. Introduction

In the context of the global economy, a major importance is the maintenance of the quality of stored agricultural products intended for use as seeding, the food industry and animal husbandry. Depending on weather conditions at harvest [1], the physical properties of agricultural seeds may be different, so when are harvested, they may have a different relative humidity having a maximum permissible value of 21%. Ensuring the optimal storage conditions of agricultural products, in order to avoid their deterioration or contamination due to mycotoxin factors is required the ensuring a low moisture content of the samples. In this sense, in the specialized literature it is recommended that the maximum value of the humidity of the stored cereal agricultural products does not exceed the maximum value of 14%. [2, 3] Consequently, regardless of the method, the moisture content of the harvested agricultural product must be reduced before storage.

Current trends in ensuring a healthier diet have stimulated the growing demand for oats for human consumption even though oats were initially used as feed. Farmers recognize the uniqueness of the nutritional qualities of oats, which have a high content in high quality protein with a low energy content, resulting in easier digestion.

Scientific research [2] in the field has shown that oat is a special cereal product, it does not contain gluten and has a high content of lipids beneficial to the body. In the case of oats, the enzymes associated with lipids are activated during industrial milling, so as oat oils are of nutritional importance in the content of oat products resulting from milling.

Among cereals, oats have the highest concentration of lipids that provide a significant amount of energy in human or animal nutrition, oat fatty essential oils are unsaturated with a high content of linoleic acid, an acid beneficial to the body and which allows the reduction of the amount of blood cholesterol serum [4]. Depending on the variety of oats [5], the concentration of lipids can vary and reaches values between 3.1-11.6%, oils which can be easily extracted.

The variation of the individual concentration of fatty acids in oat crops depends on the type of selected oat and can be manipulated by genetic modification of the seeds. The medium values in composition of fatty acids from oat reaches the percentage of 0.6% for myritic acid, 18.9% for palmitic acid, 1.6% for stearic acid, 36.4% for the oleic acid and 40.5% for the linoleic acid [2].

The oat drying operation presumes reduction of its moisture content, through exposure to a thermal field of the sample. Thus, the reduction of the moisture content of the oats, without a qualitative deterioration of it, is a problem of interest, having a high degree of complexity. The reduction of the moisture content is achieved by exposing the sample to a thermal field [6, 7], which implies the continuous control of the temperature values of the thermal field so as the maximum value of the temperature during drying do not exceed 70 degrees.

The specialized literature [8-13] presents the versatility of adapting microwave technologies in different industrial applications. Unlike conventional drying methods [3], microwave drying technologies are environmentally friendly, having a number of advantages [8-13] such as selective heating by transmitting energy directly to the entire volume of the dielectric thus reducing processing time, and the energy consumed, ensuring a rapid release of moisture content. Also the process allows automatic real-time control of the entire process by continuously monitoring the humidity and temperature, the quality of the resulting product being superior compared to other drying methods. Compared to conventional installations, the microwave system has smaller construction dimensions, less components, respectively the maintenance costs are substantially reduced.

Researches in the field [14-16], point out the fact that an important issue is to determine the energy values that should be applied to the seed bed so as the free water to be removed without affecting the integrity of the sample. In the literature [17-19], are presented different computations approaches used for the complex analysis of the high frequency electromagnetic field problems. The researches performed in the paper study the microwave drying possibilities of the oats. For the beginning a numerical model associated to the problem is numerical computed by the means of finite element method, resulting the field values. Further, the obtained numerical results were used during experiments to set-up the microwave drying. The microwave drying process studied in the paper presents an important issue due to increase grain storing request once with the climate changing opening new directions for future researches in the field, due to its advantages in improving the drying process efficiency without affecting the quality of the products.

II. The Drying Mechanism

The drying of agricultural cereal products is a simultaneous process of heat and mass transfer, in which the moisture content of the wet material (in this case oat seeds), is reduced to a level that gives it safety in storage and distribution, as well as in keeping its qualities. Researches in the field presents different technologies used for the reduction of relative humidity for different agricultural products [1], [4]. The drying operation involves in this case the transfer of heat to the macro-particles and can be performed by: convection, conduction, or high frequency electromagnetic radiation.

The convection drying is based on a convective heat transfer from the heated air to the solids (in our case oats) [1]. The hot air is forced to pass through a fixed layer of grains, heats them and then drives to the process of diffusion of moisture that results during drying. Although the drying rate can be increased by increasing the air temperature, there is still a limit to the air temperature around which the phenomenon of grain overheating can occur, especially in the areas adjacent to the air inlet. Overheating leads to cracking of the grains [4], decrease of the standard weight, and decrease of the content of trace elements and of course their germination capacity. Usually the convection drying process [2] is performed with a high energy consumption, because the entire seeds bed is heated to the evaporation temperature, to ensure an adequate heat flow. For this, powerful electric fans are used to blow hot air through the material, air that is heated using conventional fuels (gaseous or liquid), which by combustion pollutes the atmosphere.

The conduction drying [3], reduces moisture when the grains come in contact with a heated surface, or other moisture-absorbing granular material. Currently, the drying of agricultural cereal products by conduction using other granular materials (such as silica gel, or zeolites, etc.) is restricted due to the separation problems involved in the recycling process of macro-particles used as a medium for drying grains.

Currently, the trends are to develop new technologies that use microwaves and radio frequency that produce the inverse temperature gradient, so as the temperature is produced directly in the sample instead of at its surface [5], [7]. The energy absorption of the microwaves in the sample and the generation of the thermal field in its, is mainly due to the presence of water in free form.

The water gradient inside the sample can be estimate through its magnitude as follows:

$$d = \frac{2 \cdot \left(h_i - h_{he}\right)}{s} \tag{1}$$

where it was considered the moisture inside the sample h_i, the moisture of surrounding environment according to hygroscopic balance $h_{he,}$ and the thickness of the material.

The detailed mechanics [8], [10] of the conversion of microwave energy into heat, concludes that the dielectric parameters of the materials and the frequency are the main factors that lead to the heating of the materials.

The dielectric properties of a considerate oat sample exposed to microwave field is straight dependent on moisture contain, temperature and the field frequency. In the technical literature the dielectric properties of the oat sample are described through there material permittivity [6]. The complex permittivity can be written as function of dielectric constant ε', dielectric loss factor ε'' and the permittivity of free space ε_0:

$$\varepsilon^* = (\varepsilon' - j\varepsilon'')\,\varepsilon_0 \tag{2}$$

where *j* is the complex operator.

Fig. 1 and Fig. 2 presents the variation of dielectric constant and the loss factor function of frequency and moisture. As can be seen the dielectric properties of the sample are straight dependent on the field frequency, samples moisture, varying also with temperature.

It is known the fact that the dielectric properties of a sample also affect the power attenuation of the electromagnetic waves as they penetrate the loss material so as the thermal field distribution. The penetration depth (p_d) can be defined as the distance from the surface of the sample at which the power drops to 1/e (36.8%) from its value at the surface of the sample:

$$p_d = \frac{\lambda_0 \sqrt{\varepsilon'}}{2\pi\varepsilon''} \tag{3}$$

where λ_0 is the free space wavelength.

Prediction of the penetration depth during microwave processing with respect to the irregular dependence on dielectric loss factor with the temperature and the moisture content in the case of oat seeds, during microwave drying process is a tedious task [14].

The large versatility of microwave processing technology increases its request in different commercial domains [5, 10]. The essential conditions in the case of microwave processing are represented by the precise control of the applied microwave power and the uniform distribution in the sample of the thermal [16], so the microwave applicator must be designed to meet these objectives. The applicator surface wave is one of those devices that have been used successfully along with coupling microwave energy transfer [13, 20].

During microwave drying of oat, a complicated diffusion problem appears. Thermal field dispersion in the seed bed represents an important issue due to the inner evaporation where the nonhomogeneous pressure field interferes due to vapours [12]. In this case, the water migrates from the high temperatures region to areas with lower temperatures, resulting the condensation in cold spots. The fast occurrence of vapours from the inside structure of the sample can cause its destruction. From these reasons the microwave drying process must be accomplished by air stream.

Starting from the above issues is studied the continuous microwave drying of oat seeds. The considered microwave drying system is designed with six 1 kW magnetrons and permit the continuous feeding and processing of the oat seeds. The oat seeds displacement inside the microwave applicator is realised with a helical screw conveyor, which ensure also the homogenization of the thermal field resulted in oats once with it exposer to microwave field. A schematic representation of the system is presented in Fig. 3.

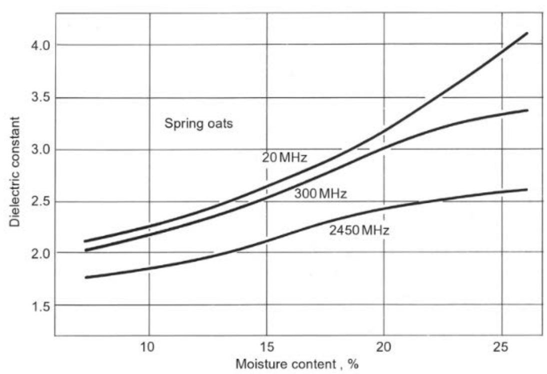

Fig. 1. Variation of the Dielectric Constant of Spring Oats with Moisture Contain at Indicated Frequency [6].

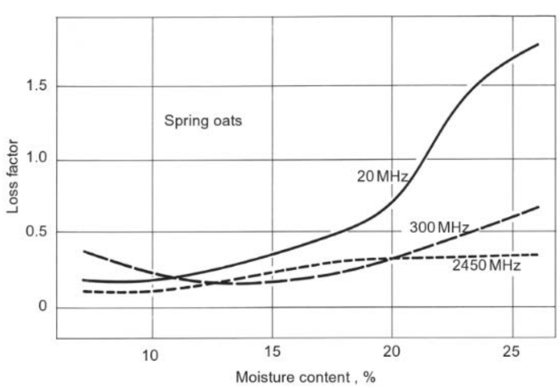

Fig. 2. Variation of the Loss Factor of Spring Oats with Moisture Contain at Indicated Frequency [6].

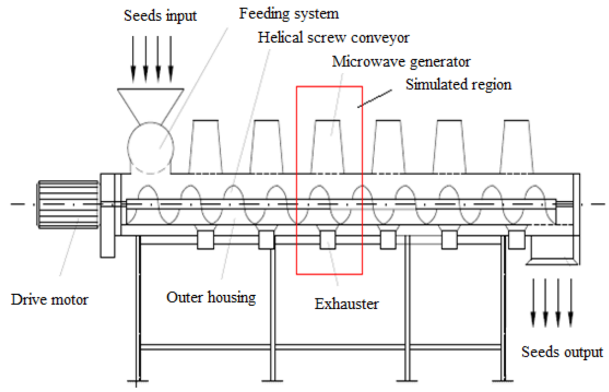

Fig. 3. Microwave Drying System.

III. Field Problem Formulae

The design of microwave heating systems with respect to applicator sizing and the selection of the appropriate microwave generators is not an easy issue. Researches from the field offers analytical models for their design [17-19]. Approach takes into account the dielectric parameters modification during their microwave processing, becoming a complex problem. Sometimes from these reasons, the approach of the problem simplified [17].

The drying proposed procedure is initially numerical analysed in order to obtain an overview upon the field values inside the microwave applicator. The numerical simulation of the microwave drying process it was proceed by considering the frequency transient state. The obtained numerical results with respect to in time exposure of the sample to microwave field will be used in the second part of the research to setup the working conditions of the microwave drying system used for spring oat drying. The considered numerical model presumes to solve Maxwell's equations for the sinusoidal regime. In this sense it is supposed as known the transversal electric wave E_t on port. On the rest of the conducting walls the transversal electric wave E_t, as well as the internal and external field sources will be imposed equal to zero. The considered model will presume to solve of the equation (4), which takes into account the relative magnetic permeability μ_r; the electric field strength $\boldsymbol{E}$; the wave factor k; the relative electric permittivity ε_r; the electric conductivity σ; the pulsation of sinusoidal quantities ω and the free space permittivity ε_0:

$$\nabla \times (\mu_r^{-1} \nabla \times \boldsymbol{E}) - k^2 (\varepsilon_r - j\sigma/\omega\varepsilon_0)\boldsymbol{E} = 0 \qquad (4)$$

In the model will be considered similar working conditions of the microwave drying system. In this sense the applicators work frequency is 2.45GHz, as well as the cavity excitation mode, the dielectric's characteristics and the above boundary conditions.

Thermal field developed into processed sample in the microwave applicator is computed for the transient regime, which can be associated to Joule's effect [17], considering the heating of the material, and the heat transfer by conduction.

$$-\,divk\ \mathrm{grad}T + c\frac{\partial T}{\partial t} = p \qquad (5)$$

where were considered: the volume power density p in [W/m^3], the density ρ [kg/m^3], the specific heat C_p in [J/kg°C], the temperature T [°C], the thermal conductivity λ [W/m°C].

In order to solve the thermal field question, the following boundary condition is imposed:

$$-\lambda\frac{\partial \mathrm{T}}{\partial \mathrm{n}}=\alpha(\mathrm{T}-\mathrm{T}_0) \quad (6)$$

where was considered the thermal convection coefficient α in [W/m^2°C] and the temperature on the dielectric's boundary domain and in the air T_0 in [°C].

The initial value of the temperature used for the dielectric's boundary in the air domain $T = T_0$ (T_0 = 23°C) was considered for the thermal problem in the dielectric's boundary condition. The thermal insulation is imposed as: $-\mathbf{n}\cdot(-\lambda\nabla \mathrm{T})=0$.

The whole domain is meshed by using tetrahedral elements, resulting the discretization network. Equation (4) is solved by the means of finite element method by using the same mesh as the electric problem, with an extra fine mesh in the processed sample and a less fine in the rest of the geometry.

Thermal field in the processed sample and its dispersion represents an important issue. Due to the inner evaporation the complicated water diffusion problem appear due to the nonhomogeneous pressure field interferes of the vapours. The fast occurrence of vapours from the inside structure of the sample can cause its destruction. Taking into account this concerns, the maximum temperature of the sample must be limited to maximum 70°C [2, 4]. In consequence will be considered only the evaporation of the surface of the sample, the inner evaporation being neglected. The evaporation speed over the sample surface is straight dependent of the surface sample temperature and the surrounding temperature with respect to the vapours saturation degree, air pressure and air flow in the vicinity of the sample [17].

It will be admitted that the evaporation speed on the surface unit will be the same on the entire surface with it linearly dependence on temperature:

$$\frac{\mathrm{d}\tau_{\mathrm{s}}}{\partial t}=w(T-T_e) \quad (7)$$

where the evaporated volume of water on the surface unit is τ_s, and evaporated volume of water at a difference of 1°C is w.

If Λ is the latent heat of vaporization volume, the heat loss due to vaporization on the surface will reduces the temperature on the surface in the manner of thermal convection. From this reason, we can consider the vaporization by introducing the fictive convection coefficient, according to the relation:

$$\alpha_{\mathrm{ech}}=\alpha+\Lambda w \quad (8)$$

This coefficient will be considered as part of boundary condition, so we have:

$$-\lambda\frac{\partial T}{\partial n}=\alpha_{\mathrm{ech}}(T-T_e) \quad (9)$$

To determine the temperature field over the interval [t_i, t_{i+1}] will allow the determination of water volume evaporated over this interval, according to relation (7):

$$-(V_{water}^{i+1}-V_{water}^{i})=\int_{t_i}^{t_{i+1}}\left(\oint_{\partial\Omega} wT\mathrm{d}l\right)\mathrm{d}t \quad (10)$$

The moisture becomes:

$$\mathrm{m}^{i+1}=\frac{\gamma_{water}V_{water}^{i+1}}{\gamma_{water}V_{water}^{i+1}+\gamma_s V_s} \quad (11)$$

where: V_s is the volume of the charge and γ_{water} and γ_s, are water densities over the surface.

To determine the percentage of moisture removed from the seeds bed using weight of the sample before drying m_i and after drying m_u (STAS 10349 /1-87):

$$H=\frac{\mathrm{m}^{i}-\mathrm{m}^{i+1}}{\mathrm{m}^{i+1}}\times 100[\%] \quad (12)$$

To the above mentioned conditions is added also the limitation condition of moisture leap: $m^i – m^{i+1} < H$, where H is the imposed moisture variation. These has to be smaller than the final moisture in order to avoid the apparition of the negative moistures. If the difference of moisture will exceed this limit, then the time step will get smaller. The material parameters of the sample depend on temperature and moisture, and are rectified for each time step.

IV. Numerical Simulation and Results

Numerical simulation was pursued to obtain the electromagnetic field dispersion in the dielectric's volume; temperature dependence on applied microwave power, and not least the drying characteristic of the considerate dielectric material (spring oat).

The numerical simulation is performed by using a numerical analysis software where a Frequency – Transient problem is defined. Due to the symmetry of the system was considered only the applicator associated to one of the magnetrons. The geometrical dimensions of the microwave applicator are defined as 345×240×250 [mm], similar to the one of the laboratory equipment. The walls of the microwave applicator and waveguide are defined as Aluminium. The oat sample is placed inside the applicator with a 60 [mm] air layer on top of it. During numerical computation, the spring oat with it properties for 22% humidity (ε'=2.5, ε''=0.3 and tgδ=0.14, ρ=780 kg/m^3, λ=0.15 W/mK and C_p=1.5 kJ/kgK were considered [2, 6]. In the defined problem was considered an extra fine mesh for the dielectric material, and a coarse mesh for the rest of the analysed geometry.

In the following some results of the simulation are presented in order to distinguishing the details concerning electric field distribution in the seed bed placed into the applicator. For a better view in Fig. 4 is presented the complex electric field strength dispersion inside the microwave applicator and dielectric material is presented, pointing out the energy supplied through the microwave port, placed on the top of the microwave applicator.

The reflected power to the magnetron expressed through the S Parameters (dB) presented in Fig. 5 is computed also. Considering the obtained results, after the rigueur transformations, it observed that if the reflected power to the waveguide tends to minimum, a higher quantity of possible power may be absorbed by the dielectric material. Based on the obtained field values, it was computed the time dependence temperature in the dielectric material with respect to microwave power. The time dependence of temperature was computed in the volume of the sample. During computation was considered that the sample was exposed to constant microwave power for 300 seconds.

Fig. 6 presents the time variation of temperature for different vales of the applied microwave power. The considerate values used during computation are: in the first case was considered a 0.25 [W/g] applied microwave power; in the second case 0.50 [W/g]; in the third case 0.75 [W/g]; in the fourth case 1.00 [W/g]; and in the fifth case 1.25 [W/g]. Taking into account the fact that this drying process should be continuous, the exposure to microwave energy should be shorter to insure the processing of a larger amount of seeds, but without affecting their quality. In order to assure a good balance between the humidity release and the quality of the sample should not exceed 90°C.

By analysing Fig. 6, we can see that for the first 2 cases, when the samples were exposed to 0.25 [W/g] and 0.50 [W/g] microwave power, the obtained temperatures in the seed volume can hardly reach 43.23 [°C] in the first case and 52.31[°C] in the second case of analysis. By analysing the rest of the cases, when the sample was expose to 0.75 [W/g], 1.00[W/g] and 1.25[W/g] microwave power, the temperature reaches values of 67.14[°C], 85.09[°C] and 101.57[°C].

The aim of research was to determine the most appropriate value of microwave power and processing time for the considerate microwave drying system in order to dry a considerate product without affecting its structure. From the specialty literature it is known that a temperature over 90°C can destroy the quality of agricultural products.

The most suitable value imposed for the microwave power with respect to the quality of the product for the 300 seconds exposure time should be with a value between 0,75 – 1,00 [W/g]. In Fig. 7 is represented the drying characteristic for the 1,00 [W/g] imposed microwave power.

For each numerical simulation were recorded the temperatures in the whole volume of the dielectric material. The objective of the study is to find out the appropriate values for exposure time and the applied microwave power.

The most appropriate value of the microwave power and processing time in order to dry the mass of seeds without affecting its structure.

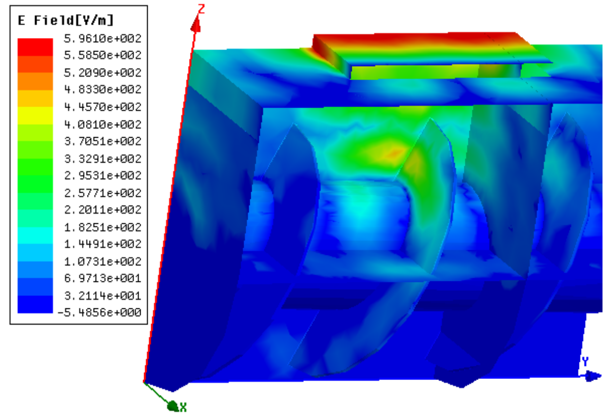

Fig. 4. Electric Field Strength Dispersion within the Microwave Dryer.

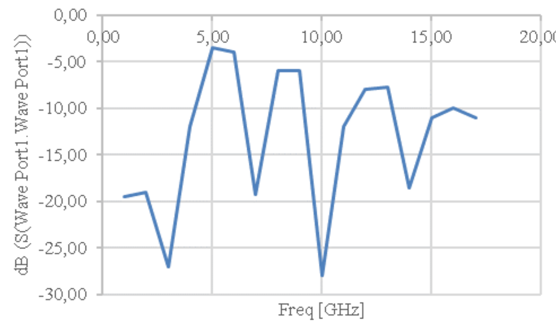

Fig. 5. Reflected Power to the Magnetron S Parameter.

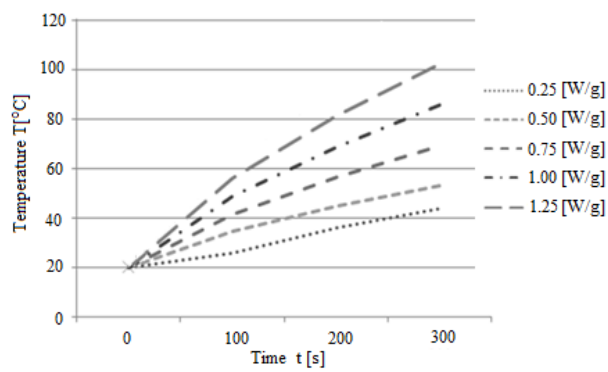

Fig. 6. Values of the Maximum Temperature Calculated in the Mass of the Oat According to Microwave Power at a Processing Time of 300[s].

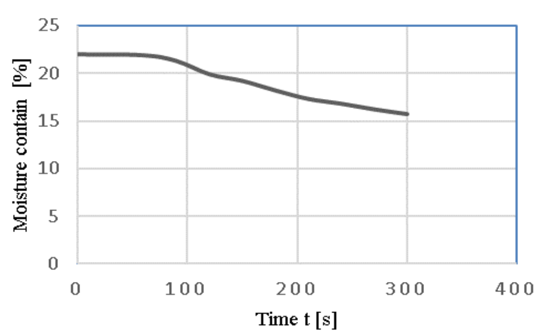

Fig. 7. In Time Moisture Dependence of the Oat Sample for of 1.00 [W/g] and Processing Time of 300 [s].

V. Conclusions

Unlike other methods of humidity reduction, the studied method has a higher value to allow a faster release of moisture content from the entire volume of material processed in the high frequency electromagnetic field, thus resulting in a substantial reduction in use time and thus creating efficiency technological process.

The obtained results present information regarding the improvement in quality of the stored oat seeds through an environmentally friendly technology.

The obtained numerical results offer important information regarding microwave drying procedure applied to oat seeds. Through simulation are known the characteristic parameters of the electromagnetic and thermal field drying process, values that are vital to adapt the operation parameters of the microwave drying systems.

In order to homogenize the thermal field inside the microwave applicator, it is necessary to set the grain in motion so as the drying process is uniform into entire volume of the product. Also, in order to facilitate the release of water vapours resulted on the seeds surface following the pressure field, the microwave drying equipment must be equipped with an exhaust system that removes excess water from the air through the air stream created in the cereal bed.

The increase of the microwave power to which the material to be processed is exposed, leads to a faster increase of the thermal field in the material. However, the maximum permissible grain temperature limit must be taken into account so that the quality of the product is maintained at high values, so as the applied microwave power must be adapted with respect to the in real-time temperature.

The aim of the study was to determine what conditions of temperature, humidity and power are favourable the percentage of moisture removed from the seeds (STAS 10349/1-87) bed. By analysing all results, we can say that the drying procedure which involve the use of constant applied microwave power of 1.00 [W/g] combined with air stream offers the fastest drying condition with respect to seeds quality.

Acknowledgment

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Optimization of Production Processes using BPMN and ArchiMate

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***Abstract*—This article aims to map and optimize production processes through the graphical form using syntax combination of BPMN and ArchiMate. In the first phase, the existing business processes of the manufacturing company in the Czech Republic were analyzed. In the second phase, the optimization of production processes was subsequently proposed. These optimizations were based on a combination of two ArchiMate and BPMN syntaxes with implementing ERP systems, enabling the design to utilize more efficient modern technology. The as-is-to-be process was documented in BPMN and ArchiMate, and a process-based simulation tool was used to quantify the effects of process improvement.**

***Keywords*—Production processes; graphic modelling; BPMN; ArchiMate**

I. Introduction

Today, ICT has become an integral part of any business. Companies that were able to use systems that helped automate processes had a significant advantage in the market and were ahead of the competition. That is why graphical notations have been created to reflect the critical areas of business architecture from the business and IT perspective. These methods can be used to identify the weaknesses of the company and propose the necessary measures to remedy them. Graphic business architecture is currently one of the essential tools that a company should address to improve its current market situation. [1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [11]

Production is defined as an activity that a company carries out to provide products or services from which it obtains money from its customers. If production were focused solely on economic and social aspects, it would find itself in a situation where all production resources are used efficiently. Production efficiency is one of the most critical factors for the company's success. However, nowadays, when machines occupy a large part of the production, it is complicated to get ahead of the competition without buying new and more efficient machines. However, business processes can be better analyzed and identified. Thus, to improve the current situation not only in terms of production but also thanks to more excellent knowledge of production processes by individual workers.

Over the years, methods for proper production management have been gradually developed in industrialized countries, leading to increased efficiency. These methods are based on certain principles and philosophical approaches to production management that were implemented and recognized in their time. Their common feature is that they were created primarily to eliminate the inefficiency and waste of previously used methods in production control [12], [13], [14], [15]. Among the best known are:

- Material Requirement Planning (MRP)
- Manufacturing Resource Planning (MRP II)
- Enterprise Resource Planning (ERP)
- Optimized Production Technology (OPT)
- Just-in-time (JIT)
- Kanban
- Lean management

Graphic business architecture is currently one of the essential tools that a company should address to improve its current market situation. However, visual mapping also has its drawbacks, especially the time-consuming modelling and the low availability of aggregate materials from which to draw [16], [17], [18], [19], [20], [21], [22]. Many decision-making or simulation approaches can be used to support decision-making and process optimization. Among the best known are, for example, System Dynamics [23], [24], [25], [26], [27] or agent-based modelling [28], [29]. Often the company decides for reengineering after applying non-standard decision-making methods [30], [31], [32], [33].

This paper deals with the use of ArchiMate and BPMN languages for business architecture modelling. Each of these languages is a bit different, and each has an altered purpose, but both serve to map business architecture graphically. This work will combine both notations and utilize the necessary elements of ArchiMate language diagrams and the orientation on BPMN process modelling. A combination of modelling approaches is dealt with for example in publications [34], [35], [36], [37], [38].

The paper is divided into the following parts. The Background section briefly provides essential information on the approaches that are central to this paper. Section III. presents the current state, i.e. it describes partial diagrams belonging to the AS-IS model. Section IV. deals with the part of the model affected by the customer. The following, Section V shows the design of a TO-BE model for individual parts of the system. Section VI briefly summarizes the effectiveness of the proposed changes. In Section VII, we discuss the possibilities of using BPMN and ArchiMate in production companies, including a possible generalization of the presented approach. Finally, the Conclusion section summarizes the results and benefits of this study.

A. Industry 4.0

A separate and nowadays much-solved chapter of Production management is Industry 4.0, which is an advanced strategy of the German government aimed at automating the industry. It is based on cyber-physical systems (this system consists of physical entities that are controlled by computer algorithms, based on the cooperation of separate computing units that can make autonomous decisions) deployed to devices used in common areas of life. This primarily distinguishes industry 4.0 from ordinary automation of production systems and is therefore also called four industrial revolutions/ evolution. The basis is the Internet of Things (IoT), which is designed to enable the connection of a wide variety of internet-connected devices, which will open up new possibilities for controlling, monitoring, communicating and connecting home appliances, cars, but also medical devices. To deploy this system, all production facilities must include integrated communication standards through which CPS will communicate with those facilities. Industry 4.0 defines the concept of a digital factory into an intelligent factory that is adaptable, resource-efficient, ergonomic (human-friendly) and integrating customers and business partners into business processes. The arrival of IoT enables the transition from mass production to customer-oriented production. Production takes place in small batches and individual output, while there is no increase in the price of products. Automated machines and other smart tools used in industry 4.0 communicate wirelessly with IT systems that have a cloud solution. The combination of physical devices with their virtual data leads not only to improving production processes but also to changing the value chain from product design through production and logistics to recycling. For the introduction of Industry 4.0, it will be necessary to replace most of the existing business processes from product development to post-warranty service. However, the new intelligent factories with the help of IoT will not only be able to improve the quality and traceability of individual processes. Hence, products made precisely to different customer requirements, but will also enhance customer communication. Not only will it be able to monitor the condition of its product, but also the company can monitor predictive maintenance and thus optimize its production capacity.

II. Theoretical Background

A. Process Management

The process approach is based on the condition that the basic object of management is a described, clearly defined, structured, resource and input secured process that is created for a specific customer and having a clearly defined owner. The task of each process is to provide a product or service to one particular customer concerning its defined requirements, established rules and restrictions. The process requires some inputs and can use the resources assigned to it. A process is, therefore, a set of activities that interact and transform inputs into outputs.

Worth mentioning is also a functional approach to corporate governance, which is already outdated and ineffective. However, many companies are still using it abundantly today, and because of established practices do not even want to leave. The functional approach consists of a division of labour, in which the work is divided into the most straightforward tasks so that a certain number of specialists can perform even unskilled workers. This approach led to the introduction of mass production and the division of labour among functional units created based on their skills. This structure is also in line with the organizational structure, where the company is divided into divisions and individual departments, where each department only performs its tasks. However, it no longer follows the entire flow of business processes. In the case of this functional approach, each transition between processes, between departments, represents a risk point in terms of information barrier and time loss. The organization is then driven by the needs of each department and, to increase productivity as a whole, the productivity of each functional unit must be increased separately. Today, however, customers are very much involved in production and production is adjusted to their requirements. A functional approach is no longer practical and will not be sustainable for companies in the future.

In contrast to the functional approach, which places the main emphasis on the organizational division of skills, the process approach to management is oriented not only on the result of work (product) but also on the sequence of activities that lead to the achievement of the given product. Work is not performed in individual departments that are separated from each other, but work flows through these departments. Customer needs then drive the whole system. By using the process approach, the individual processes are gradually improved, thus optimizing them and simplifying the entire workflow. Both the title and the text imply that process management is based on business processes. To transition to this style of management is essential for a company to know its primary processes and be an expert in the field it is involved in because a company that does not know its processes cannot even want to improve those processes. On the other hand, when the main processes are known, it is possible to remove unnecessary processes and focus the company's forces on the main ones that will be further developed.

B. BPMN

Business Process Modeling and Notation (BPMN) is a graphical notation used to describe business processes. The primary goal of BPMN is to provide a notation that is easily understood by business departments and IT departments. The basis of BPMN is to create a description of a sequence of activities in a company, including events accompanying a process or communication between entities. BPMN was initially created by the non-profit Business Process Management Initiative (BPMI), which initially sought to set the standard for business processes as a means of developing e-business and B2B. To create graphical models, the Business Process Modeling Language (BPML), based on the XML syntax, was designed to define the same rules for all stakeholders. It has become a meta-language for business data modelling. This language was open, and everyone could download it from the BPMI website. However, since it was necessary to create a notation for this language that would be easy and understandable for everyone using this language, the BPMN notation was created. BPMN is, therefore, a standard for XML-based languages (e.g. BPML).

C. ArchiMate

ArchiMate is an open modelling language for graphical representation of business architecture, currently managed by The Open Group. The latest version 3.0.1, which was released in June 2016, is now in use and has been greatly enhanced and improved over the original version 2.1. The ArchiMate language is used to create a comprehensive view of the company but is not designed to develop too detailed models. Therefore, it is necessary to choose the right level of detail and thus, the appropriate language. However, none of the languages should go beyond their purpose and some degree of detail, as the description would become too detailed and could not fulfil its intended purpose. As mentioned earlier, ArchiMate can be linked to other languages [34], such as UML or BPMN, which can model selected areas in more detail. Both ArchiMate and BPMN use business processes for modelling, but the difference is in their application. ArchiMate models processes at the abstract level that are necessary for the design of enterprise architecture but are not designed for detailed process modelling. In contrast, BPMN is designed to model more detailed processes involving atomic tiles. ArchiMate is even closer to UML since most elements and constraints are based on UML. ArchiMate itself is not a methodology, but it is based on the TOGAF methodology, which includes methods and tools for creating, maintaining and managing business architecture. TOGAF emphasizes the creation of individual architectural steps aimed at constructing uniform models tailored to organizations. The structure of the ArchiMate language consists of 3 main parts (business layer, application layer and technology layers), which are complemented by motivational extension, implementation and migration extension completing the entire TOGAF framework [39].

III. Production: Graphical Modeling the As-Is Processes

A. Collecting Information

An exemplary example of the production of a standardized company was chosen to give a practical illustration of the above process. The company is engaged in the development of information systems for medium-sized companies. In addition to the creation of information systems, the offer also provides support services to customers, such as cloud computing, maintenance and possible complaints solutions or additional implementation of individual modules. Clients of the company are companies located primarily in the manufacturing industry. The customer can purchase the system itself and have it deployed to its servers, or it can only buy the system as a service and access the system remotely, and it will be stored on the developer's servers.

First, the models of the company providing the ERP system will be created and described and in the next step the customer models will be created so that the ERP system can be created according to these diagrams.

B. Organizational Structure of the Business Model

The ERP system builder, who is the supplier in this model, implements all the services that are depicted in the services provided to them. The services consist of the main services that are part of the purchased system, such as Maintenance, System Implementation, System Consulting and Training. Maintenance is a one-year service where the supplier provides free maintenance, performance improvement, or attribute modification. Under this service, we can see the system upgrade and help desk, which the customer can contact at any time. Another service is, of course, the implementation of the system, which is also related to the trial test operation. Consultations with the customer are processed during the systems development and training of all employees who will use the system. The rest of the services are additionally available and can be ordered at any time by the customer. All these services are provided to the customer through the offered ERP system. In this model shown in Fig. 1, the manufacturing company is in the customer's role. The case of using some of the services it makes payments to the supplier for these services.

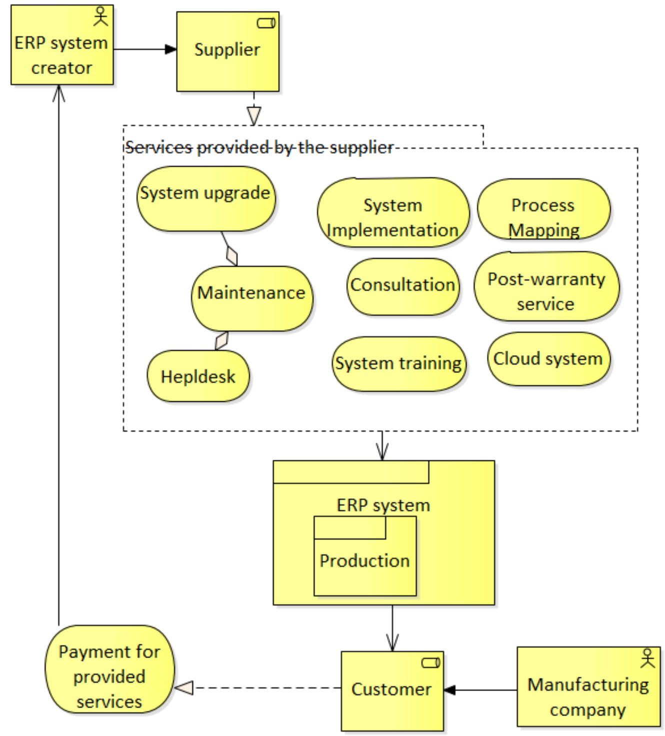

Fig. 1. Organizational Structure of the Business Model

C. Modelling of Business Processes of ERP System - Main Process

Because of describing only one ERP system module, the top-level model does not start, i.e. business processes, but shows the primary process of the production module. Also, this process does not create all the activities that can be carried out in the production department. However, it only models the system activities that are important for the development company and also for the presentation to the customer.

Fig. 2 describes the top view of the entire production process from system setup, through production planning to product handover. The figure shows that two types of events can initiate production. If the system configuration needs to be done first, the process is triggered by the first Production Implementation Start event. The system configuration activity

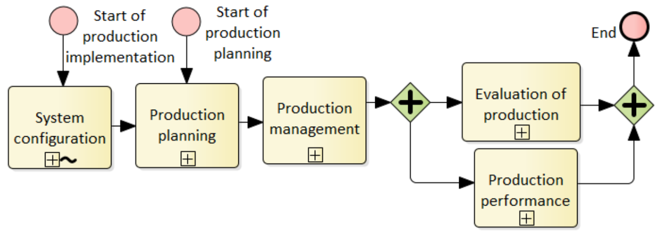

Fig. 2. The Main Production Module Process

itself is of the Ad-hoc type, that is, all nested activities can run in any order, but never two at the same time. After the system configuration is complete, the process flow continues to the Production Planning activity. This activity can also be initiated by the second event of the planned production start process. In this case, there is no system configuration, but the process starts right away in the second activity, where production is planned. After this activity, the flow continues to the Production Control, where the documentation containing the production operations themselves, the issue of material from the warehouse and the payroll slips are printed. In the next step, the flow is split and triggers both Production Performance and Production Evaluation activities simultaneously. The process can only be completed when both of these activities are completed.

1) System Configuration: A process is describing setting up the entire system so that the individual production orders are numbered according to specific rules. Determine the different products according to the specified parameters—the setting of specific tools, operations and all other components for proper system operation. Activities are nested in an Ad-hoc subprocess, so there are no links between them.

2) Production Planning: Process, see Fig. 3, describe the commencement of production operations. The process itself has two startup events. The first event, "Targeted Production Planning", occurs when the production needs to be managed directly for a given customer. In this case, a production order is already created from the sales order that has already been created. In the second case, production is unaddressed, i.e. products that are intended to replenish stocks in stock will be produced. MRP calculation is then performed from both start events. After its preparation, the requirements for the production itself are processed. After processing the request, production is planned and ready for production.

3) MRP Calculation: This process, shown in Fig. 4, describes the Analysis of Production and Sales Orders and their subsequent processing. In the first process activity, these orders are processed in terms of inventory that is in stock. Find out if there is enough material or semi-finished product or already manufactured products in stock to cover the entire order. There may be several results at this point. First of all, there is a situation in which there is enough material in stock to produce. Therefore only the production requirement is created. In the latter case, there may be a situation where there is no more material available for production and must be secured through the sales department. That creates a purchase requirement to purchase the requested material. The third case is that only part of the production material is in stock. It is then necessary to

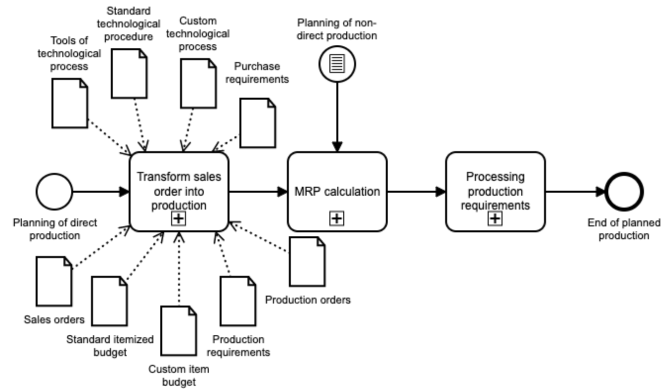

Fig. 3. Production Planning

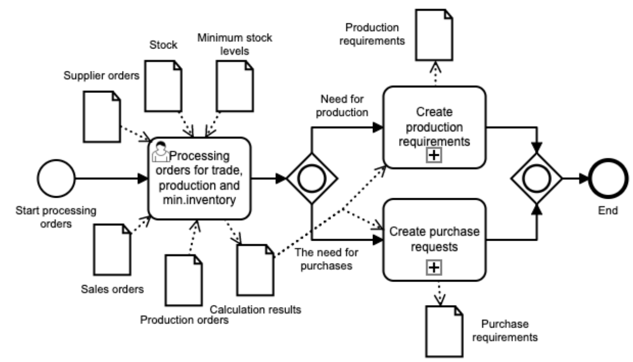

Fig. 4. MRP Calculation

create both production requirements to produce products from the remaining material and a purchase requirement to replenish the stock of required material.

4) Production request processing: The process illustrated in Fig. 5 describes the refinement of production requirements. One requirement can be precise from internal product parameters, drawings or customer wishes. After specifying the requirement, individual operations are generated, which must be performed to complete the product.

5) Production Management: The whole process begins with the event that the production order is included in production. After placing the order, the accompanying documentation is printed. This documentation contains the actual production operations, material delivery from the warehouse and payroll cards. The accompanying production documentation controls the individual production operations, the issue of the material is necessary for the dispensing of the required material from the warehouse, and the wage cards are referred to by the production workers, where they record the hours worked on the production of the given product. These documents may take various forms. If no other components are implemented, the process ends. If operational costing is still implemented, the Activity Costing Processing activity takes place. In another case, when the Operational Production Control is implemented, the so-called activity takes place. If the order analysis component is implemented, the so-called activity is implemented.

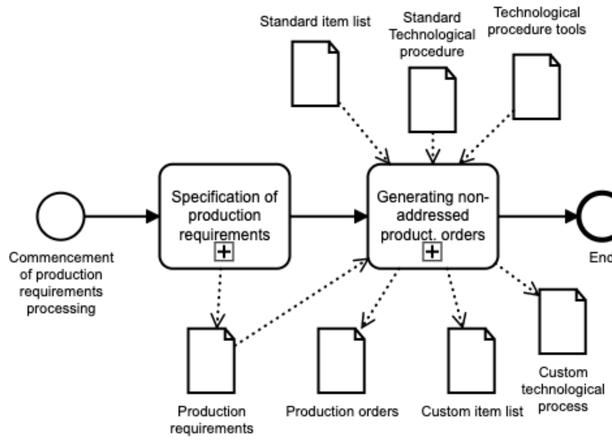

Fig. 5. Production Request Processing

The customer may have all or some of the additional functions implemented. At any step in this process, the Custom TPV Change Request event can be triggered. That is because the trigger is non-interrupting, and so triggering does not affect the operation of the second process. Depending on the situation, either the order or technological BOMs continue to be updated, or both can be updated.

6) Operational Production Control: Two events initiate this process; the first event is an automatic trigger after a given time interval. So it happens automatically. The second event is the manual start of the process and is determined by man. The first activity after these events is Move operations to the work stack, where the next process is determined. There may be other activities such as allocating the necessary material for the task and assigning work to individual workers, where the payroll sheets for allocation are printed. When the production resource allocation function is implemented for production, there is a capacity allocation before the work is allocated. Here the paths are divided whether the capacity allocation is done manually or automatically.

D. Production Performance

Two events initiate this process; one event is the processing of a given operation in production. The second event is to restart the next action. After these events, the Select Report Mode activity is performed, i.e. it is selected whether the operation will be initiated, interrupted, terminated or reported. These activities are either performed with or without allocation. After selecting and executing start, stop, or end activities, the reported asset will be processed, and if no asset is found for non-compliance, the process is complete. Either the process is repeated for another operation, or will not be repeated at the end of all production. If a report type activity is selected, a non-compliance check is performed.

If no mismatch is found, the process ends or is repeated. However, if an error is found, a report on non-conforming production shall be made. If a termination type activity is selected, a nonconformity check is performed, and if not found, the report assets are processed, and the flow continues as mentioned. However, if an error has been found, the documentation for non-conforming production shall be recorded. The documentation for reporting and non-compliance shall be processed. Then the process is either terminated again or is running over another operation.

1) Evaluation of Production: This process is simplified and put to the highest level, although it is apparent that all individual flows should be in separate sub-processes. The following activities are performed in this process: Production output is posted. The output is converted into wages, i.e. the work of individual employees is allocated to salaries, and the results of the whole calculation are processed. After all these activities have been completed, the evaluation of the production is over.

E. Application Layer

The application layer, shown in Fig. 6, provides a global view of the offered system and an overview of the modules and services that are offered. The diagram further describes that an ERP system consists of a module of production, trade, capacity planning, costing, shipping and sales that cannot be used without purchasing a module of sales. In case of interest, the customer can buy other systems such as CRM, Economy or HR module, which can be connected to the ERP system. The ERP system component thus shows all possible modules that the customer can buy and also what other systems and interconnections the company offers and enables. The production module is connected with services that these applications can be provided to the customer within the ERP system. The services that the system vendor depicts as application applications enter the customer's processes as business services that help execute business processes.

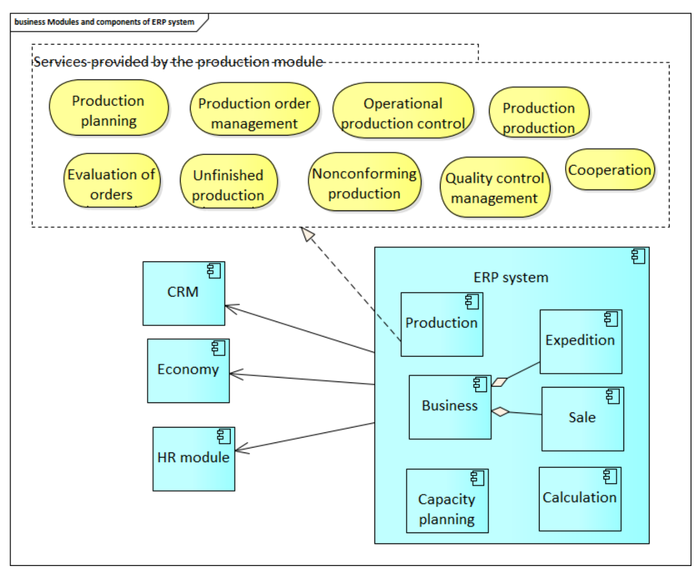

Fig. 6. Modules and Components of ERP System

IV. Modelling at the Customer

A. Defining Goals

When arriving at a customer, the most important thing is to find out what their goals are and why they want to replace the existing one or introduce a new system. These goals and requirements will help not only modellers but also the development company to identify what parts of the processes it is essential to focus on. The model captures the company's goals to be achieved after the implementation of the new ERP system. The strategic goal of the highest level deals with the improvement of the current situation in the company. To achieve this, the objectives at the lower level to which this objective is falling must be met. Enabling the reading of the QR code can be realized by the introduction of portable readers that allow the code to be read. Product improvement, according to customer requirements, can be realized by monitoring all unsuccessful offers. Customer feedback and subsequent analysis of the reasons for rejection will be collected for these offers. The goal of improving work efficiency is further broken down into two other sub-goals, which are Process Automation and Replacement of Existing Systems by One. Both of these goals can be implemented by deploying a new ERP system that allows automatic processing of some manual activities and also replaces existing systems with one system, resulting in greater system stability and increased ease of training for new staff. This principle The deployment of a new ERP system is crucial as it also positively influences (the plus sign of the binding) the introduction of portable QR readers and monitoring the reasons for rejection of the offer. On the principle of the new ERP system deployment, there are also three requirements, which are defined by the customer. In case of request modelling in BPMN, this model can serve as a basis for their creation. Looking at this diagram, shown in Fig. 7, some limitations could jeopardize the realization of the illustrated goals, such as sufficient HW to implement the system. However, if the customer does not have certain constraints along with the requirements, it is better to leave these rather speculative limitations to possible models, where the issue will be solved and not limit the model at all.

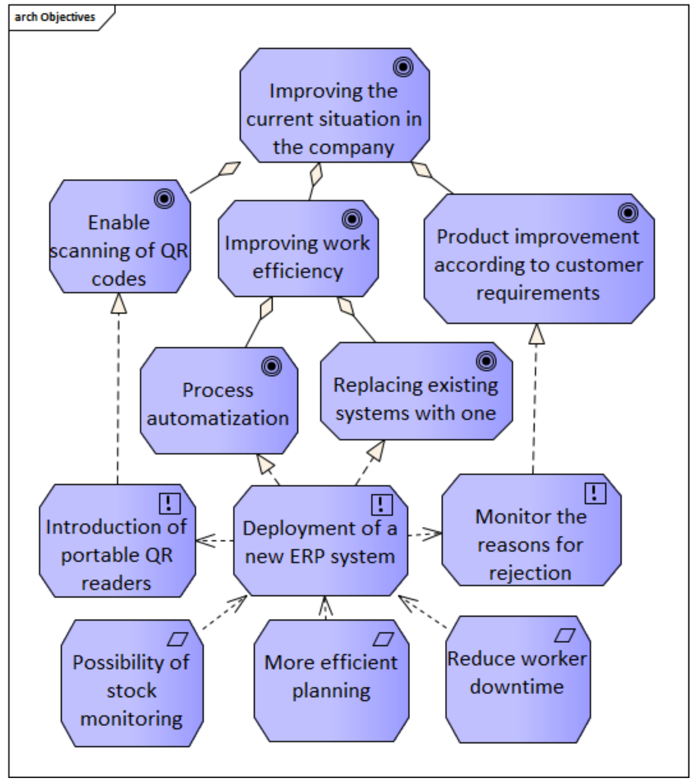

Fig. 7. Objectives

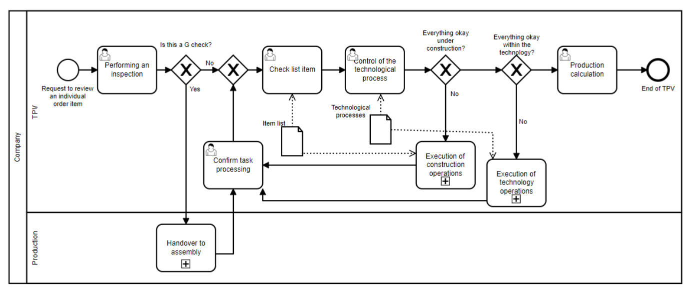

Fig. 8. Technological Preparation of Production

B. Technological Preparation of Production

Technological preparation of production (TPV) is not the production process itself. Still, it is closely connected with it, and as can be seen in Fig. 8, production processes appear here, and this part is most often part of the production module.

After the sale is complete, the TPV process is started, as shown in the business process diagram. When the sales contract is created and printed in the sale, the TPV process is started. First of all, the G check is carried out. It is a check whether a new product will be manufactured or whether a request for overhaul, modification or, for example, a product complaint has been received. In this case, the product is G, and it continues to be assembled to perform some of the above operations. If it is not a G product, the process proceeds to check the item list where the user in the system must check all subassemblies, parts and source material from which it will be produced. Next, the user performs the technological process check-in parallel with the item list check. Upon completion of both checks, the flow continues to condition that everything within the structure is OK. If not, the flow proceeds to the design where the design changes are made, which must be acknowledged, and the flow goes back to check the item list and process flow. This cycle is carried out until everything within the structure is in order. It must then be ascertained if all is well within the technology, and the process is proceeding in a similar way to the construction condition. After a successful technological check, a calculation is made, and the TPV process is terminated.

C. Backbone Production Process

If the business process breaks down into multiple levels and not just one, as was the case with the TPV process, it is advisable to create a second level from a subprocess that will contain the process itself, and the knife will also drop to even lower levels. This diagram, shown in Fig. 9, is elementary: first, the production will be started, then the assembly and the final product will be dispatched. However, there are events between the sub-processes that contain the condition, and without meeting the condition, the flow cannot continue to the next process. Taking into account, for example, the conditional event between production and assembly, it is clear that assembly cannot begin until all the necessary parts are available to the final product composition.

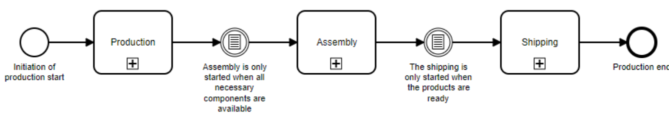

Fig. 9. Backbone Production Process

D. Production

The production process, shown in Fig. 10, begins with its planning. As mentioned above, this process will further disintegrate and will be described below, as its complexity could lead to a large diagram and its confusion. The next step in the process is to assign work to specific workers. In this activity, work will be progressively allocated to each worker until all the work is divided. The worker takes his assigned work and goes to do it. After the product has been produced, the work must be physically submitted. After submitting it, the worker must go to the computer and specify that the work is complete. In the system, in the Job Assignment section, the employee appears with a marker available to enter a new job, indicating that the current job is already done. At the moment, but the product is not finished yet. It must first undergo quality control before being labelled as a finished product. The manufacturing worker does not have to wait for this fact and can already produce another product. The next step is to pass the cover sheet back to the planning, and if it was not the last operation of the product, the work is assigned to the worker. In the case of the previous operation in the accompanying document, the product will be stored and registered. However, it must first be decided whether it is the final product and will go to the finished product warehouse or a semi-finished product that will go to another warehouse.

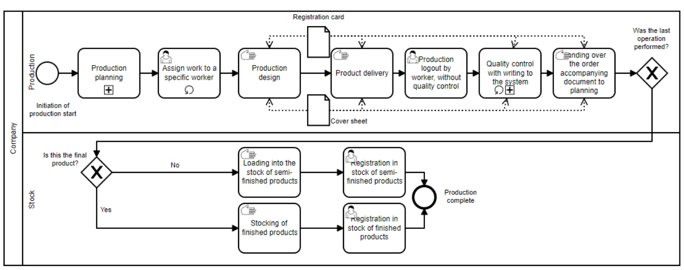

Fig. 10. Production

E. Production Planning

This process takes place at the very beginning of the production process. Thus, before all the activities described in the previous diagram. For a general view of production, however, this detailed planning process is not needed, and therefore, it is put down to a lower level and described at this point. The user finds a specific order in the system, for which he has to find the parts from which the product will be composed. They must create a production plan for these parts and print the accompanying documentation. In this step, it is worth noting the trigger of the message type (Receiving a new production order). This event will be referenced in the following quality control process. After the accompanying documentation has been printed, it must be decided whether it is a finished product - then the product labels are printed. In the case of the production of semi-finished products, the flow continues on the condition, whether it is a W order. Production orders are divided according to the number of pieces produced, if there are 20 or more pieces, the production order is marked with the letter W and registration plates must be printed. In another case, it proceeds straight to the work stack, from which it continues to be used for assigning tasks to individual workers.

F. Quality Control with Writing to the System

In production, it is possible to see a sub-process of checking that is performed for each product separately. The process, shown in Fig. 11, is started when the employee submits the product as finished. The inspector conducts a quality check. If the check is OK, logs off the product in the system with the check performed. That completes the inspection process and can resume production. If the product has not been inspected according to the product requirements, it must be entered into the inspection report system, and a committee is called to assess the next steps of the product. If the product cannot be repaired, two manual activities are performed in parallel: Transfer the product to the scrap store, where this inspection thread is terminated, and the second activity Urgency evaluation of the product. Here it is decided whether the non-compliant product must be re-manufactured or can be dispensed with. This decision can be made because the so-called economic benefits plan some products. That means that when a user intends to manufacture, he will enter the number of products that will be most advantageous to manufacture, taking into account the cost of manufacturing and storing unused products. Thanks to this, there can be a requirement, e.g. ten products, of which two are bad, but only one is required to order, and therefore it is not necessary to produce another product again, and this fibre is terminated.

In the second case, the user creates a new production order, and it is sent. Here we can notice the end event of the message type. In this step, it is useful to remember the production planning and trigger event of the same kind. This event is triggered only by the Send Documentation Report from the Quality Control event. The arrival of that report restarts production planning, but not at the beginning of the process. It restarts from the Print Documentation Activity that triggers the receipt of the report.

If the product can be repaired, the need for a change in TPV will be reviewed. Assuming that a TPV modification request is entered, the technological process is manually modified and submitted to planning. The process thread ends by sending a product repair start message back to production planning. This part is similar to the creation of a new order. With the difference that the process does not start with the printing of the accompanying documentation, but the modified technological procedure is inserted directly into the work tank.

G. Construction

Fig. 12 shows the assembly process. The assembly of the product begins after all the parts needed to assemble the final product are in stock. The process initiates the users entering the

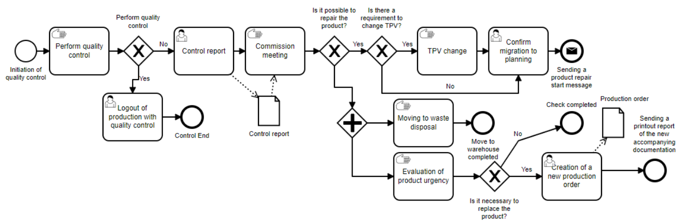

Fig. 11. Quality Control with Writing to the System

information about the material, which needs to be picked for the given product. Entered products are picked and delivered for assembly, where the product is finalized to the required state. The assembled product is submitted for quality control, and all operations performed on the product are entered into the system. In the next step, a quality check is carried out to determine whether the product complies with the requirements, as in the production part. If the product is not correct, it is returned to the assembly. For a product that has been inspected, it is assessed whether it is necessary to paint it as required. If so, it is painted and stored. If there is no need to paint the product, it is transported directly to the finished product warehouse and registered in the complete product system.

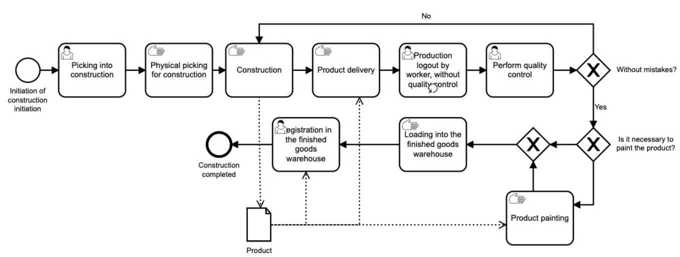

Fig. 12. Construction

H. The Current State of the Technological Part of the Company

Fig. 13 describes the current state of the technological infrastructure of the company so that it is clear where the new system will intervene and what system or hardware will use this new system. The diagram shows that the buildings of the manufacturing company are located at three different locations and communication is carried out via the Internet. That means that the system will also need to be secured for communication outside the intranet. The headquarters of the company contains a database and application server, which together with workstations and production machines are connected via a local network. The company headquarters communicates with the warehouses via the Internet, except for the semi-finished warehouse located directly in the headquarters. In the second location, called the Butcher Shop, there is only a workstation with a barcode reader and a firewall that accesses the servers via the Internet. Furthermore, there is a cutting machine that only represents the purpose of the location, but is not connected to the system. In the third location, External Workstation, the workstation is located just like in all other locations. Besides, there is a simple automatic stacker that loads goods based on barcodes.

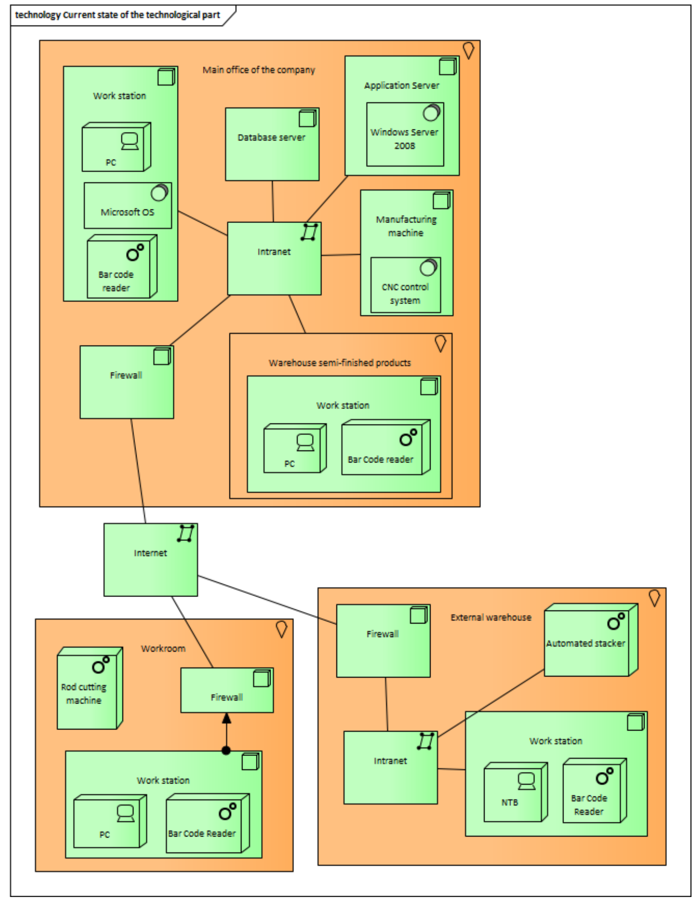

Fig. 13. Current State of the Technological Part

V. Results: Process Analysis and Development of the To-Be Process

A. Process Evaluation

After creating the as-is model, the process was evaluated with a focus on weaknesses and potential for improvement. The evaluation is based on two quality criteria, efficiency and effectiveness. Harrington [40] defined the process efficiency as “the extent to which the outputs of a process or sub-process meet the needs and expectations of its customers”. The effectiveness of the process then refers to “the extent to which resources are minimized, and wastage is eliminated when seeking efficiency”. In our case, we evaluated process efficiency as fulfilling the necessary process functions, while process efficiency was assessed by identifying the bottleneck of the process.

B. Target State of the Technological Part of the Company

The general processes of the ERP system and the processes of the manufacturing company itself differ considerably. However, it is possible to start a large part of the activities and use these activities in the implementation of the new system. When designing a solution, there must be no transformation and effort to adjust the activities of the manufacturing company so that it is as simple as possible to deploy the system. Still, the system itself has to be modified. System creation is usually customer-oriented. That means that the current system is being modified according to the client's requirements to achieve the highest possible satisfaction. In the following years, he turned to the relevant supplier again. However, the customer is satisfied when if the system works well, and the workers do good work. Moreover, since most people are poorly accepting changes and taking every new thing as unnecessary, human processes must not change to a large extent, but, above all, there is a change in the processes that the computer is doing. The target state of business processes and technological part is realized by projecting changes into the models of the current state of the company.

C. Impacts on Technological Preparation of Production

Like the business process model, the TPV process, shown in Fig. 14 is based on the current state of the company and tries to maintain the same processes that they already have in the company. Nevertheless, many changes have been made to this process, especially the automation of some activities. Before the process starts, it can be known whether the activity G is not performed by the employee, or is replaced by the system. It decides whether it is a G order and, if not, the flow continues to three parallel activities for which two employees are no longer needed, but the system executes them on its own. Here, too, there was one activity, which is Control for the actual product. In this activity, the system checks whether the order contains all the necessary requisites, such as the filled-in product name, whether the goods group is correctly entered or whether the item number is filled in. The flow continues in the usual way through several conditions until a new condition is established to determine if MRP calculation has already been performed. In case the calculation has not yet been calculated for a given order, two new activities are launched simultaneously. MRP calculation itself and checking the last cost calculation for the final product. If the calculation for the product exists and is less than half a year, the TPV process is terminated. Otherwise, we have to make a new calculation, confirm it, and the process goes back to the checks.

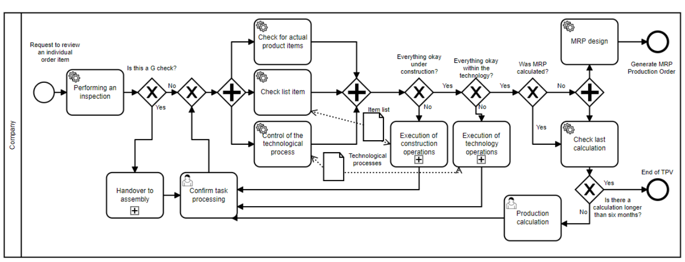

Fig. 14. TPV

D. MRP Calculation

As already mentioned, this process is new, but its considerable similarity can be seen in the production planning process except that the system only performs the whole process. The process is started by generating a production order from the TPV process and starts processing the individual lines of the business order. Then, a Disintegration Check is performed to detect items disintegration. These create an overview of which materials and blanks the part is produced from. Find out if it is a purchased item, or the product is already in stock. In this case, the MRP calculation would be terminated. Otherwise, a production order is created, and the accompanying documentation is printed. In this production planning process, the patron was notified of a message trigger event. That is replaced by a signal event that is triggered by another part of the system. After printing the accompanying documentation, the production order is entered in the order sheet. After this step, under the same condition, it is decided whether to print the product labels that the system generates and prints. Registration labels are already replaced by QR codes and are always printed for each job. The MRP calculation process, shown in Fig. 15, ends when the order is generated to the work stack.

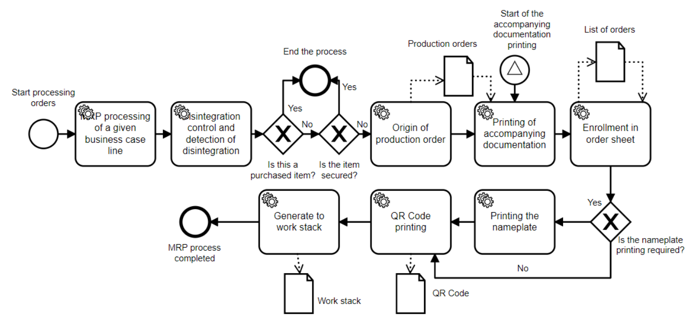

Fig. 15. MRP Calculation

E. Target State of the Backbone Production Process

There were two changes in the backbone process in Fig. 16. First of all, it is possible to notice a timer trigger. The production process is automatically started 20 minutes after midnight. Also, there is the Workshop Planning activity, in which the system schedules production times for each order, as well as the approximate number of orders that should be produced per working day. That means that planning staff does not have to plan the entire production, but only assigns tasks.

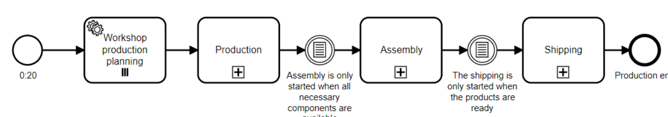

Fig. 16. Target State of the Backbone Production Process

F. Production

Production, Fig. 17, begins with acceptance of the accompanying document for production. Here, only workers assign work to individual workers, and they can start working. Until now, this activity could not be entirely replaced by the system because the human factor and knowledge of workers are continuously required when assigning work (e.g. worker A may produce three products in the same time as worker B only 2). Another significant change is the handing over of the finished product. The worker will no longer have to go physically to hand over the product and then unsubscribe in the system, but this step can be performed simultaneously. That will be possible with the use of portable QR readers located directly at the product delivery point. The worker will retrieve the location where the product will be placed, as well as the product code. That will lead to simplification of work, but also ensure that no other component than the final product is to be used during assembly.

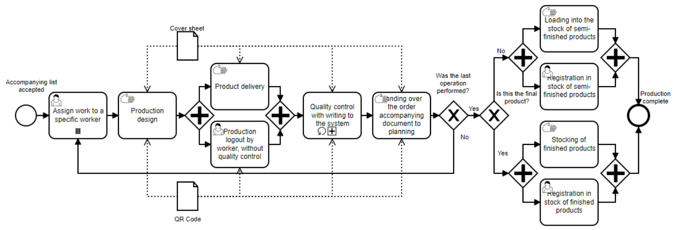

Fig. 17. Target Production Model

G. Target State of Quality Control

As it is possible to see in Fig. 18, there were no significant changes in quality control as in other processes. The changes mainly relate to non-repairable products, the so-called scrap: their transfer to the scrap store is newly recorded in the system. Due to using a QR reader is possible to perform these activities together, as well as when handing in other products. Another change occurs when evaluating whether it is necessary to manufacture the defective product again. The worker will no longer create this task, but the decision will be made automatically by the system. It is up to the worker to develop a new production order. There were also two end events: from message to signal. That is because workers no longer carry out production planning, but the system performs this process. Thus, the user only needs to create a new order or production plan, and the system automatically moves it to the MRP process.

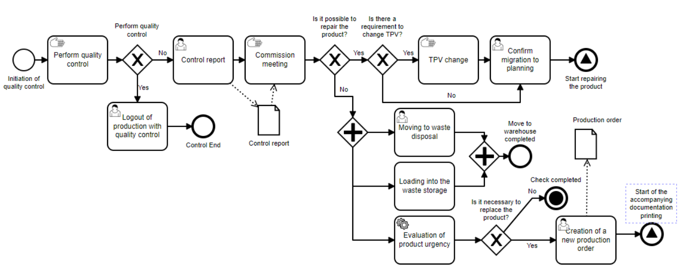

Fig. 18. Target State of Quality Control

H. Target Construction Status

The construction to-be model shown in Fig. 19 only simplified the picking and delivery of products by introducing QR codes. The rest of the construction process remains unchanged.

I. Target State of the Technological Part of the Company

To implement the ERP system is necessary to replace the existing application server with a new, more powerful, as it is possible to see in Fig. 20. The ERP system will be performed on this server, which will be accessed by both existing computer stations and newly acquired QR readers. Another change is the QR readers mentioned above, which will replace old computer stations used only for barcode reading.

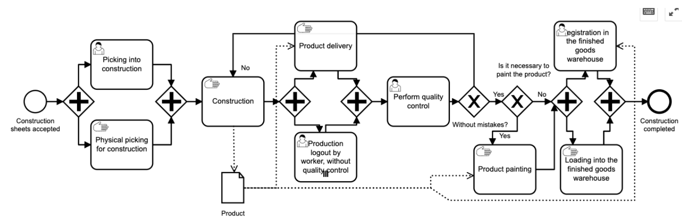

Fig. 19. Target Construction Model

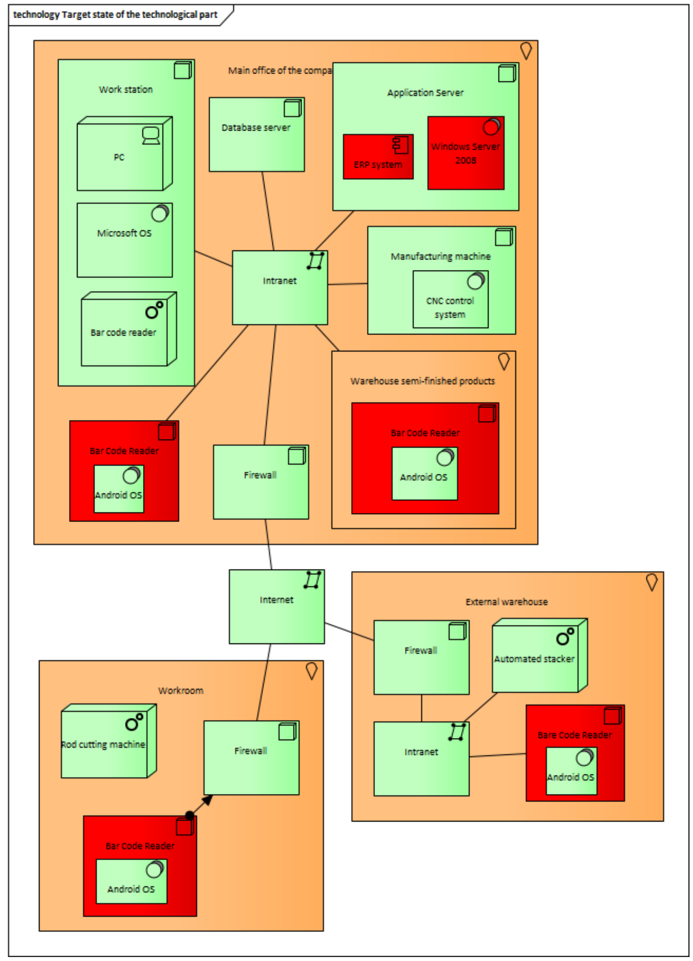

Fig. 20. Target State of the Technological Part

VI. Quantifying the Impact

The primary function of the as-is and to-be process models in the improvement project was to facilitate communication between key stakeholders. The process layout was designed as simple as possible to minimize the technical impact of the modelling tools used. After analyzing the production process, the weaknesses and improvement potential was understood. The company requested to illustrate the potential financial impact of the new process design using a simulation approach. For this purpose, the existing process maps needed to be extended. All data on time required for individual activities as are necessary for financial analysis were obtained from the company. An expert estimate estimated the system load of the proposed new activities and service bags.

The simulation showed significant differences in cycle time between as-is and to-be scenarios. Since the time saved by the design of the to-be process has brought additional process capacity, the economic return on carrying out the future process is mainly in the potential increase in profitability due to additional capacity.

VII. Discussion

The mapping of enterprise architecture is possible also by the use of other ArchiMate diagrams. E.g., an organizational structure diagram or diagram of enterprise standards. However, especially network and data infrastructures diagrams can currently be used to analyze data security within the GDPR (General Data Protection Regulation). Processes modelled with BPMN could be enhanced with business process simulations that can show how they can be optimized to make them as efficient as possible for the business. The languages introduced in the thesis can be further enriched by UML, which would add complexity to the whole modelling and thus enable to capture more levels of enterprise architecture.

The generalizability of the presented model and approach can be discussed in terms of methods and focus. In Article [41], the authors stated that ArchiMate and The Value Management Platform (VMP) could be connected. They also proved that ArchiMate value streams, capabilities and resources are all strategy layer elements in the enterprise architecture, reflecting a level of abstraction in modelling common to VMP. In Article [42], the authors examined the limitations of the ArchiMate and SOMF languages. The paper [43] elaborates an adaptation of the profile mechanism from UML for generic extensions of meta models in the field of enterprise modelling.

VIII. Conclusions

The interconnection of the ERP system together with QR code readers, will bring a positive effect not only for the manufacturing company but also for employees, who will be relieved of some of their work. The management will be able to monitor the progress of various operations and the movement of materials and products, thus avoiding the use of defective parts and improving the company's visibility. With the help of estimates and predictions, planning of both short-term and long-term goals will be much easier. With the help of process automation, the company can use the full potential of workers who have been delayed by demanding activities and could not fully devote themselves to their work. That will also help the night running of the system. However, setting up new processes related to the implementation of a new system and changing the technological infrastructure may also entail certain risks that a company must consider before deploying the system.

Acknowledgment

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Cluster based Detection and Reduction Techniques to Identify Wormhole Attacks in Underwater Wireless Sensor Networks

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***Abstract*—Underwater Wireless Sensor Networks (UWSN) is widely used in variety of applications but none of the applications have taken network security into considerations. Deployment of underwater network is a challenging task and because of the hash underwater environment, the network is vulnerable to large class of security attacks. Recent research on underwater communication focuses mainly on energy efficiency, network connectivity and maximum communication range. The nature of underwater sensor network makes it more attractive for the attackers. One of the most serious problems in underwater networks is wormhole attack. In this research work we concentrate on providing security to the underwater network against wormhole attacks. We introduce the wormhole attack in the network and propose a solution to detect this attack in underwater wireless networks. Energy Efficient Hybrid Optical - Acoustic Cluster Based Routing Protocol (EEHRCP) is incorporated and using the round trip time and other characteristics of wormhole attack, the presence of the wormhole attack in the network is identified. The simulation results depicts that the proposed wormhole detection mechanism increases throughput by 26%, reduces energy consumption by 3%, reduces end to end delay by 13% and increases packet delivery ratio by 3%.**

Keywords*—*Underwater communication; wormhole attack; round trip time; EEHRCP

I. Introduction

UWSN are used for variety of applications like military, pollution monitoring, disaster maintaining etc. Because of the hash underwater environment, fast node mobility, water pressure, temperature, salinity, lack of topology make them vulnerable to large range of security attacks. Traditional security mechanism cannot be applied to underwater network because they are heavy and require large number of computations. Underwater nodes are less energy efficient and the energy level of the nodes get drained due to movement, so nodes cannot waste their energy level in large computation to provide security against attacks [1-2].

Underwater channel have some special characteristics that makes it different from other sensor networks. These characteristics are listed below.

- Nodes battery level, memory space is limited, and nodes batteries cannot be easily recharged.
- UWSN are self-configuring and self-organizing as the node mobility is high and they drift with water.
- The topology changes rapidly.
- The control of sensor nodes is centralized which is located near the shore so that it can be easily located using GPS and it can be easily replaced in case of occurrences of any faults.

UWSN are vulnerable to large kind of attacks. These attacks can be classified as data security attacks, Denial of Service (DOS) attack, replication attack and physical attacks [3]. Among these DOS attack is a serious threat as this attack is a passive attack. It does not make any changes to the data but simply degrades the network and both throughput and performance are reduced. The various DoS attacks are listed below.[4].

- Jamming: It is a type of DoS attack where the intruder disturbs communication by corrupting valid packets or by simply sending excess packets in order to drain the energy level of the nodes.
- Wormhole attack: In this type of attack the intruder creates a virtual path that creates an illusion to the neighbouring node that it is the shortest and efficient route. When the nodes transfer the packets through the tunnel it simply drops or corrupt the packets. Here the attackers need not the cryptographic concepts, encryption methods. It just simply needs to monitor the data transfer and just corrupt the packets.
- Spoofing attack: In this type of attack the attacker gets the ID of the legitimate node and then floods the network with broadcast and acknowledgement packets with the spoofed ID. This type of attack difficult to detect quickly as the attacker uses the legitimate node ID for spoofing [5].
- Sybil attack: In this type to attack the attacked node appears at different locations at a particular time instance. This attack degrades the routing technique used in the network.
- Selective forwarding attack: It is an attack where the attacker targets the important anchor node or central

authority node and tries to flood the node with large number of request packets. Due to which the anchor node energy level degrades quickly and node fails. This results in reduced throughput because all other sensor nodes take help of anchor node for communication [6-8].

Fig. 1 depicts the different DoS attacks in UWSN.

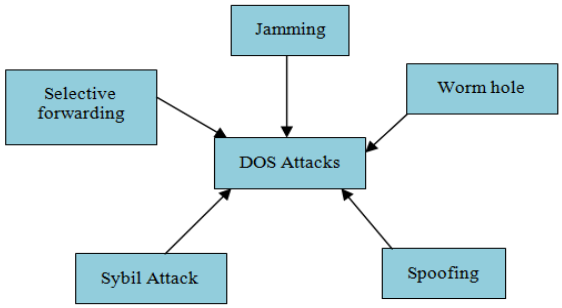

Fig. 1. Types of DOS Attacks.

In this research work we propose a methodology for identifying the wormhole attack in UWSN. The major contribution of our work can be summarized as below.

- To identify the intruder node that performs wormhole attack in the network.
- We propose a cluster based approach to detect wormhole attack.
- Simulation of the proposed algorithm is performed and compared with the existing methodologies.

The organization of the paper is as follows: Section 2 reviews the related work. Section 3 describes the wormhole detection algorithm. Section 4 presents the simulation evaluation of the proposed methodology. Conclusion and summary of research work are presented in Section 5.

II. Related Work

Wormhole attack is the route constructed by the intruder between the source and destination with less delay and high bandwidth than any other routes. Fig. 2 depicts the wormhole attack. Here a malicious node constructs the wormhole link and inform the nodes that it is the fastest and shortest link. The nodes believe that the wormhole link is shortest and thus transfer the data packets through the wormhole link. The malicious node need to just monitor the link for the packets and it then drops the packets or discards the packets as and when node transfers them [9].

Distributed wormhole attack detection is proposed by Yurong Xu, where the node calculates the hop count to its neighboring nodes. It than finds the shortest path to construct the local map. Distortion in local map is identified to detect the wormhole attack. The diameter feature is used identify wormhole link. A threshold is defined for the diameter when the node identifies that the diameter of the network cross the threshold than it immediately identifies the presence of the wormhole attack. The simulation results depicts that the proposed methodology can detection rate is around 80% and has low false alarm rate [10].

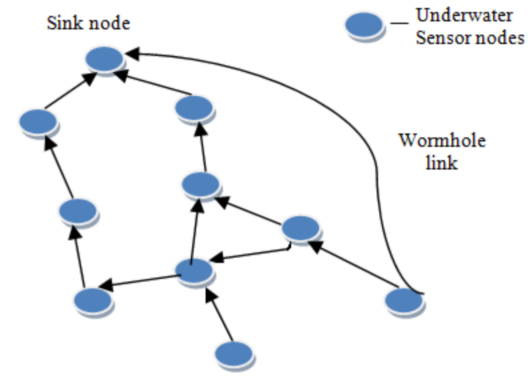

Fig. 2. Scenario for Wormhole Attack.

Rupinder Singh presents a watch dog concept based hybrid wormhole detection model where packet drop and delay at each hop is considered for detecting wormhole attack. At the time of route discovery the probability of wormhole presence is also calculated, using which packet loss probability of a node is calculated and then packet loss probability for the entire route is calculated. These probability values are used to take a decision regarding existence of wormhole attack [11].

Parmar Amish et al. proposes a solution to wormhole attack where each node maintains the routing table which consists of information about all the neighboring nodes. Before sending a packet the node checks the routing table for route information, if route information is not found than it sends a request packet and waits for reply. The destination node on receiving request packet sends back the reply packet through the same route from where it received request packet. The sender if it receives more than one reply packets it identifies that there are more than one route. Sender node than calculates the round trip time and compares it with the defined threshold, if RTT is less than threshold it identifies the wormhole attack and drops such routes [12].

Mousam A. Patel et al. proposes a wormhole detection methodology using promiscuous method and Packet Leashes methods. In promiscuous method a watchdog node continuously monitor the network it verifies the packet sent by sender and then forward it to over the route and silently watch the movement of packet. Packet leashes use the geographical location of the node and require the awareness of the location of the nodes. The methodology also uses the RTT to suspect the presence of the wormhole tunnel than the trusted neighbor nodes helps the source node to detect wormhole within the network [13].

He Ronghui et al. proposes a wormhole detection mechanism using beacon nodes. A distributed algorithm is proposed where the beacon nodes play the role of the detector. The job of the sensor nodes is to maintain the hop count with the neighboring nodes. The beacon node continuously sends an alarm message to the base station. The base station responsibility is to start the detection method and take necessary actions when attack is detected. The simulation is run by considering around 250 nodes. The proposed methodology does not require additional hardware or manual setup. It can also locate the wormhole location with minimum localization error [14].

III. Proposed System

In this section the proposed wormhole detection algorithm is discussed. The Energy Efficient Hybrid Optical - Acoustic Cluster Based Routing Protocol (EEHRCP) [15] is used as the underlying network topology. The Cluster Head (CH) plays an important role within the network. To reduce the load of the CH node a two layered approach is used. The sensor nodes are placed randomly deep inside the sea. The job of the sensor nodes is to sense the data and transform it to the CH. The CH collects all the data aggregates it and then forwards it to the surface buoys. The surface buoy communicates with the base stations where the processing of the sensed data takes place. The CH selection procedure is same as in EEHRCP. The layered approach of the network is shown in Fig. 3.

To monitor the malicious activity in the network an additional Guard Node (GN) is considered. The main purpose of utilizing the GN is to monitor the clusters and report the CH if any malicious activity found within the network. The GN is used to reduce the burden of the CH as it has to monitor the sensor nodes. When the GN informs the CH about the malicious activity, the CH has to take certain action against the intruders. The nodes underwater are critical and the energy level of the nodes should be maintained as it is very difficult to recharge the batteries of the nodes underwater. In order to save the energy level of the CH the outer layer CH2 is used to take actions against malicious activity. It is the responsibility of the CH2 to inform all the inner level nodes about the malicious activity in the cluster.

A. *Wormhole Detection Methodology*

In the proposed system each node maintains the following information

- Round Trip Time (RTT) which is the time from the source sending the packet till it receives an acknowledgement.
- Based on the hop count between source and destination the expected time of delivery ETD is estimated.
- A threshold value is set (Th) in order to tolerate the lost packets.
- Number of packets sent and received from source S to destination D is also maintained as PSent and PReceived.

Fig. 4 depicts the detection method.

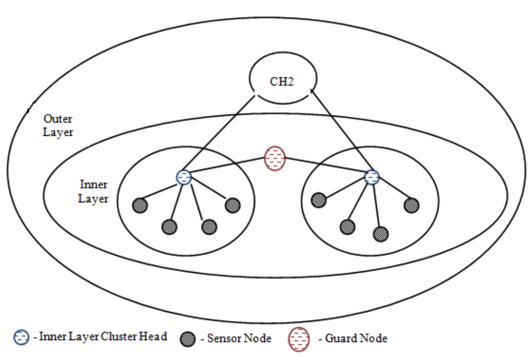

Fig. 3. Layered Approach of the Network.

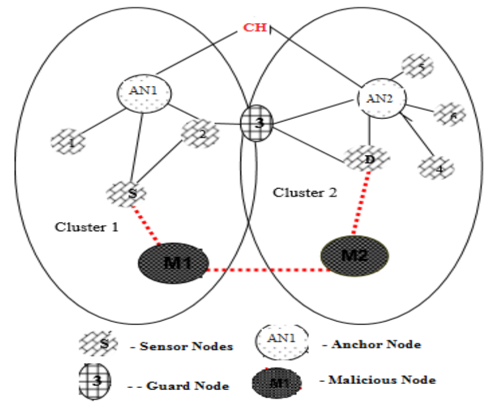

Fig. 4. Cluster based Detection Method.

In Fig. 4 source S from cluster1 wants to send data packet to Destination D in cluster2. It fetches the route from its routing able via node 2 and 3. As node 3 is closer to both the cluster it is chosen as the guard node. The malicious node M1 hears the communication from S and immediately informs other malicious node M2 from cluster2. As node 3 is chosen as guard node it keeps on monitoring the communication, when it suspects some malicious activity it immediately informs the CH. The detailed algorithm is discussed below.

B. *Wormhole Detection Algorithm*

Wormhole Detection Algorithm

Step 1: Nodes are deployed, CH is selected and the node that is nearest to both the cluster is chosen as guard node.

Step 2: S node sends a HELLO packet to D and initiates its timer t1.

Step 3: PSent = PSent +1.

Step 4: S stops timer at t2 when it receives ack from D and Calculate ETD = t2 - t1

Step 5: once connection is established S starts sending data packets and initiated timer td1 and stops at td2 when ack is received.

Step 6: Calculates RTT = td2 – td1

Step 7: if RTT < ETD

Step 8: then guard node calculates

P = PSent (S, D) – PReceived (S, D)

Step 9: Threshold (Th) = Average RTT / No . of hops

Step 10: if P > Th then

Step 11: inform CH2 regarding malicious activity.

Step 11: CH2 informs S to discard the route through M1 and follow other outer to reach D

Step 12: End

IV. Simulation and Result Discussions

In this section the simulation results for various network parameters like throughput, energy consumption, end to end delay and packet delivery ratio. The network settings and performance evaluation are also discussed.

A. Environment Settings

The environment settings used for simulation are provided in Table I.

Initially the normal EEHRCP Algorithm results are considered and the wormhole node is added in the network. The results are noted after injection of the malicious node. The proposed methodology is applied to the malicious network and the results are compared for all the three scenarios.

Table II depicts values of network throughput. Fig. 5 shows the comparison of network throughput with all the three protocols. The wormhole attack decreases the network throughput as the malicious node continuously drops the packets and degrades the throughput of the network by 48%. By applying the wormhole detection algorithm the throughput is further increased by 26%.

TABLE I. PARAMETERS USED IN EEHRCP

Parameters	Value
Network Area	1000*2000 m3
Routing Protocol	EEHRCP
No of nodes	500
Min distance between nodes	80 m
Number of sectors	16
Sensor node initial energy	10 kJ
Transmission power	2.8 w
Channel bandwidth	10 kHz
Depth	2.0 km
Mobility Model	Fixed

TABLE II. NO. OF NODES VS. NETWORK THROUGHPUT

No. of Nodes	Network Throughput (kbps)		
	Normal EEHRCP	Wormhole EEHRCP	Proposed EEHRCP
50	60	20	30
100	110	50	80
150	150	90	110
200	160	95	130
250	198	90	135
300	295	100	150
350	350	150	250
400	400	190	325
450	410	225	340
500	430	240	392

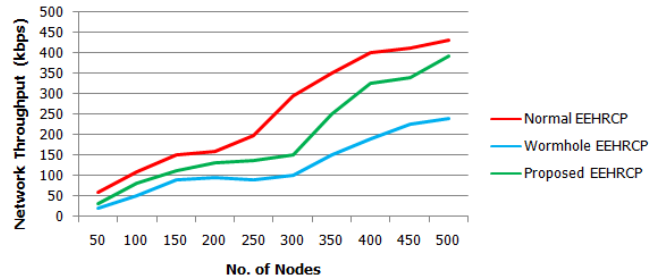

Fig. 5. Comparison of Network Throughput.

Fig. 6 shows the comparison of energy consumption and the values are depicted is Table III. As the nodes underwater are crucial and it is very difficult the recharge the battery of the sensor nodes, the energy level of the nodes should be efficiently utilized. The inclusion of the wormhole node within the network decreases the energy level of the node by 15%. Proposed wormhole EEHRCP detection algorithm further decreases the energy consumption of the node by 3% when compared with wormhole EEHRCP.

End to end delay is the time taken by the packets to reach the destination. Table IV depicts the end to end delay values and, Fig. 7 shows the comparison of end to end delay of all the three methodologies. When the wormhole attack is applied on the network the delay is increased as the malicious node corrupt or drops the packets because of which the packets do not reach the destination node. There is an increase by 16% in the delay when the network is affected by wormhole. The proposed methodology detects the wormhole attack and further reduces the delay by 13%.

The ratio of packets generated by packets delivered is packet delivery ratio, Table V depicts the paket delivery ratio and, Fig. 8 depicts the comparison of packet delivery ratio. The wormhole attacked system decreases the delivery ratio by 11% as the main intension of the malicious node is to ensure that the packets are not reached to the destination node. Further the proposed methodology identifies the attack and further increases the delivery ratio by 4% when compared to the attacked system.

TABLE III. NO. OF NODES VS. ENERGY CONSUMPTION

No. of Nodes	Average Energy Consumption (Joules)		
	Normal EEHRCP	Wormhole EEHRCP	Proposed EEHRCP
50	100	300	150
100	120	382	200
150	220	430	350
200	300	490	420
250	320	485	460
300	400	610	500
350	590	740	652
400	710	895	752
450	700	925	772
500	650	950	790

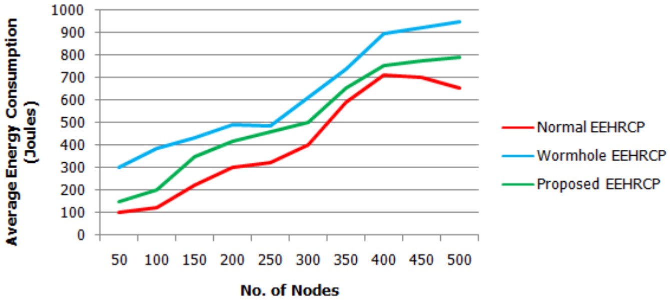

Fig. 6. Comparison of Energy Consumption.

TABLE IV. NO. OF NODES VS. END TO END DELAY

No. of Nodes	End-to-End Delay (seconds)		
	Normal EEHRCP	Wormhole EEHRCP	Proposed EEHRCP
50	10	15	13
100	8.5	12.8	11
150	6.2	10.6	8.7
200	4.8	8.2	7.6
250	4	7.4	6.3
300	3.6	6.2	4.3
350	3.8	6	5.6
400	3.4	5.8	4.3
450	3	5.6	4.2
500	2.5	5.8	4

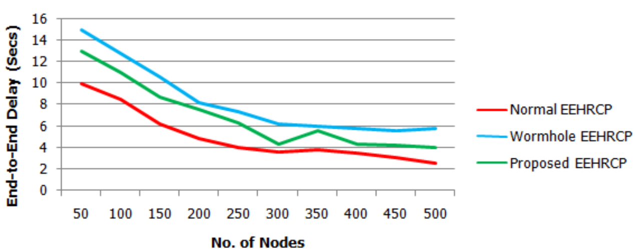

Fig. 7. Comparison of End to End Delay.

TABLE V. NO. OF NODES VS. PACKET DELIVERY RATIO

No. of Nodes	Packet Delivery Ratio		
	Normal EEHRCP	Wormhole EEHRCP	Proposed EEHRCP
50	8.2	5.2	6.5
100	8.9	5.4	6
150	9	5.8	7.5
200	9.8	6.3	8.3
250	10	7.2	8.5
300	10.4	7.3	8.9
350	10.8	7.6	9.2
400	11.3	7.6	9.3
450	12	7.9	9.6
500	12.3	8.5	9.7

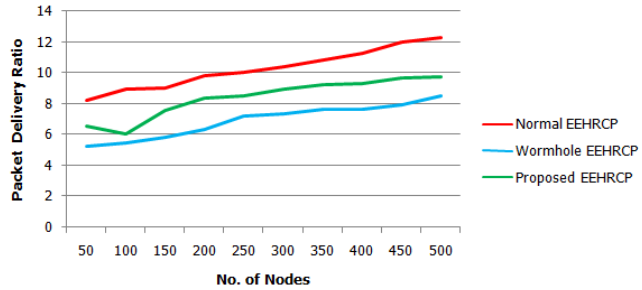

Fig. 8. Comparison of Packet Delivery Ratio.

V. CONCLUSION

One of the applications of underwater communication is military where the secret information is sent through underwater nodes, so security is the important feature that needs to be considered. Providing security to the underwater nodes is a challenging task because of the harsh underwater environment. As the nodes continuously drift with the water the network topologies continuously changes and energy of the node degrade quickly due do which managing nodes becomes challenging.

In this research work we propose a solution to the wormhole attack in the underwater communication system. Wormhole is a passive attack where the attacker need not know the encryption keys information. All that the attacker does is simply sit and listen the network for communication and then make feel the sender that the route through malicious node is a shortest path to reach the destination. As the source always chooses the shortest distance to reach the destination and forwards the packets to the malicious node. The malicious nodes simply drop or corrupt the packets send by the sender which degrades the overall performance of the network.

The wormhole attack is applied to EEHRCP algorithm and the simulation results show the comparison of Normal EEHRCP, wormhole attacked EEHRCP and proposed EEHRCP. According the simulation results the throughput is increased by 26%, energy consumption is reduced by 3%, end to end delay is reduced by 13% and packet delivery ratio is increased by 3% when compared with the wormhole affected EEHRCP algorithm.

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Effect of Multi-Frequency Beam Alignment on Non-Line-of-Site Vehicle to Infrastructure Communication using CI Model (CI-NLOS-V2I)

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***Abstract*—Investigation of the effect of beam alignment for milimeter wave (mmWave) transmission in the case of Vehicle-to-Infrastructure communication (V2I) is carried out. The investigation covered varying transmission-reception (TX-RX) distances. The effect of carrier frequency variation using different antenna angles and gains is also analyzed. The results showed convergence of path loss (PL) values regardless of angle or antenna gain (dBi). The investigation also proved that shadow fading (SF), which is related to standard deviation (σ) and exponent number (n) is a main contributor to the observed high path loss values in the case of misalignment. It is also noted that the path loss values decreases as a function of frequency per same travelled distance, which is related to the exponent number. This work highlights the importance of antenna alignment and that V2I communication can be very much optimized if and when auto-antenna alignment is used, and the importance of multi-antenna arrays.**

Keywords*—*Intelligent transportation systems; autonomous vehicles; connected vehicles; mmWave; channel model; path loss; CI Model; NLOS; V2I; V2V

I. Introduction

Connected and autonomous vehicles will play a pivotal role intelligent transportation systems in smart cities and will to a large extent depend on connectivity and communications between vehicles, hence high speed communicating nodes with low latency wireless links are critical for the success of applying the concept of smart cities. Connectivity among vehicles is of prime importance, as it contributes greatly to enhance roads safety, reduce environmental effects and provide higher level of living. Such objectives can only be achieved through provision of smart sensors with ability to transmit signals directly or through the cloud at high bit rates.

Mobile communications employing Millimeter wave (mmWave) is seen as a promising frequency band for the mobile, vehicular wireless networking as it is expected to have large spectrum. It is foreseen that it will have excellent potential in reaching extremely high data rates, which will exceed by far traditional cellular systems operating at sub-6 GHz bands [1-4].

Recently, a great interest in the design and development of vehicles capable of driving autonomously is realized and supported by research institutes and industrial organization.

Autonomous and connected vehicles and their driving technologies are important research topics in the automotive world. The vehicle technologies available at present are only a small sample of what to expect for the future. Technologies based on driver assistance are under development and directed towards autonomous vehicles (AS) and connected vehicles (CV) [5-6].

Connected vehicles are vehicles that employ various communication techniques to interface with the driver, other vehicles, roadside, and the Cloud. Theses interfaces can be used to improve vehicle safety, efficiency and commuting times. In general, vehicle communication comprises exchanging of information from a vehicle to any entity that may contribute to the functionality of the vehicle. They provide critical information to a driver or a vehicle in order to assist taking better actions. Connected vehicles principles of operation does not involve the vehicle making any decisions on behalf of the driver, contrary to Autonomous Vehicles.

Many autonomous vehicles currently in development are based on a sensory processing systems, communicating through an On Board Units (OBUs). The provision of sensors and wireless communication devices in an increasing number of vehicles is aimed at exchanging data with the vehicles, providing information to the vehicles and drivers, and collecting critical information about the vehicles activities.

II. Background

The exponential increase of vehicles with OBUs could cause an overload on the cellular network, hence, a degradation of the quality of service (QoS). For vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications, particular attention is given to the wireless access in vehicular environments [7-8].

Thus, the need for higher capacity in mobile communications is on the increase. The 5G wireless standard is trying to resolve bandwidth critical issues, such as bottleneck by including extra features like ubiquitous connectivity, significantly lower latency, and ultra-high-speed data transfers.

To achieve these objects, a more efficient use of the spectrum is required over the employed wireless communication frequency, thus leading to the concept of millimeter-wave (mmWave) [9-11].

In order to work with mmWave, a detailed knowledge of the communication channel and propagation path characteristics is essential, in order to provide the required reliable service. New challenges are faced working with very high frequencies, such as range, shadowing, fading and more importantly mobility and directional communication.

Recently, a marked progress is achieved in employing the mmWave in automotive applications, specifically in Vehicle-to-Everything (V2X) channel propagation application and transmission modeling comprising Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communications. Such communication technology is crucial for intelligent transportation of the future that includes autonomous vehicles by transcending the current wireless communications limitations, thus enabling big data exchange for a V2X communication with internet of things (IoT) interface to the cloud.

The notable rise in demands for increased mobile data rates and distributed data access have led to a choice of alternative frequency bands with a fresh spectrum allocations using the millimeter wave (mmWave) frequency bands, which is a factor in supporting the 5th generation (5G) wireless communication.

Non-Line-of-Sight (NLOS) work covering the range from above 6GHz and up to 100 GHz is carried out over the past few years in relation to urban microcells (UMi) and urban macrocells (UMa) with directional and omnidirectional setups.

Intelligent Transportation Systems (ITS) will be able to connect vehicles and infrastructure at Gbps rate. ITS will depend on vehicle-to-everything (V2X) communications to share information among vehicles. However, mmWave communication suffers from beam alignment problems due to dynamic vehicle traffic, which causes regular beam misalignment which tends to degrade performance and contributes to routing problems.

In this paper, an investigation into the effect of beam alignment for V2I communication at various GHz frequencies is carried out. The frequency range used in this work covers 4 GHz to 100 GHz range. Such spectrum is used in order to observe signal behavior change that covers all frequencies of interest in both V2I and V2V communication. A mathematical and parametric model is proposed to be used with the already established CI model [12-16].

III. THE CI PATHLOSS MODEL

Different models developed that account for path loss namely;

1) Alpha-Beta-Gamma (ABG).

2) Close-in free space reference distance with frequency weighting (CIF).

3) Close-in (CI).

All developed models are appropriate in certain environments. Thus it is very important to understand that a selected model can be used in a new application whilst continue to possess stability, reliability, efficiency, and accuracy.

For V2I communication, it is concluded from previous studies that CI model is more fitted to describe such communication pattern due to its fewer variables that need to be controlled and the very good results it produces with high reliability. CI model (dB), is given by the expression in equation (1).

$$PL(f,d) = FSPL(f,d_0) + 10n\log_{10}\left(\frac{d}{d_0}\right) + \chi_\sigma. \quad (1)$$

Where;

PL: Path loss, which is a function of Transmitter-Receiver

separation distance (d)in meters between TX and RX over a frequency range in GHz and measured in (dB)

f: Carrier frequency (GHz)

FSPL: Free Space Path Loss (dB)

n: Path loss Exponent (PLE)

d_0: Close-in free space reference distance (m)

χ_σ: Shadow fading which is zero-mean Gaussian random

variable with a standard deviation σ measured in (dB)

FSPL (dB) in equation (1) is given by the free space path loss in dB at a distance d_0 given by Friis' free space in equation (2).

$$FSPL(f,d_0) = 20\log_{10}\left(\frac{4\pi\, f\, d_0\, x10^9}{c}\right). \quad (2)$$

Where;

c: Speed of light

To show the contribution of the carrier frequency, equation (2) can be re-written as shown in equation (3).

$$FSPL(f,d_0) = 20\log_{10}\left(\frac{4\pi\, d_0\, x10^9}{c}\right). + 20\log_{10}(f) \quad (3)$$

Equation (3), can be further simplified to produce equation (4).

$$FSPL(f,d_0) = 32.4 + 20\log_{10}(f) \quad (4)$$

Combining equations (1) and (4) yields equation (5):

$$PL(f,d) = 32.4 + 10n\log_{10}\left(\frac{d}{d_0}\right) + 20\log_{10}(f) + \chi_\sigma \quad (5)$$

The CI model provide a close-in free space reference for the path loss model to have reliable functionality of transmitted power in relation to covered distance. Also, consideration in the CI model is made to cover the main usage of the communication channels to be in the far field between 1 m and the Fraunhofer distance, due to the locations where the base station (BS) antennas will be mounted. (CI) reference distance model has better accuracy, stability as compared with other models [17-20].

The close-in free space reference distance (CI) path loss model has a solid basis, and is simultaneously applicable for frequencies both below and above 6 GHz which is of interest to many applications as a step into the core of the mmWave environment. In addition, the CI path loss model demonstrates optimum parameter stability and forecasting accuracy for probable use over distances different to the original measurement range. It is favorable among other models to be used in urban microcell (UMi), urban macrocell (Uma), indoor hotspot (InH) among others compared to other path loss models with recent adoption in rural microcell (RMi) and macrocell (RMa) environments.

IV. Methodology

The main objective of this work is to study the application of the CI model on mmWaves over a frequency range 4 GHz-100 GHz for V2I communication and the contribution of the following parameters through the use of data obtained at different angles: $\theta_{new} = \theta_{old} + \Delta\theta$:

1) Effect of beam alignment between TX-RX.
2) Effect of Distance.
3) Effect of Carrier Frequency.

The approach followed in this work is based on firstly showing that when two different angled beams are aligned with their perspective transmitters through auto tracking, then their corresponding path loss values are the same or extremely close.

This can be achieved through re-writing equation (5) to obtain equation (6) [21-22].

$$PL(f,d) = n\alpha + (\beta + 32.4) + \chi_\sigma \tag{6}$$

Where;

$$\beta = 20\log_{10}(f)... \tag{6.1}$$

$$\alpha = 10\log_{10}\left(\frac{d}{d_0}\right) \tag{6.2}$$

When beam alignment for two different transmitters and receivers at different angles is achieved, then all terms for both transmitters and receivers in equation (6) should equate.

The terms in equation (6) cover all three objectives mentioned as follows:

1. Effect of Alignment and Shadow fading (SF) : χ_σ
2. Effect of distance: $\alpha = 10\log_{10}\left(\frac{d}{d_0}\right)$
3. Effect of Frequency: $\beta = 20\log_{10}(f)$

This will be proved through the obtained results and during discussion of the data obtained.

V. Results

Table I presents the two components forming path loss (PL) due to free space (FSPL) over a frequency range 4 GHz to 100 GHz, while Fig. 1 shows its characteristics.

Table II presents path loss values for two beam aligned situations at two different angles. The table presents two selected cases with the rest follow similar pattern.

TABLE I. Path Loss due to Free Space

Frequency (f) GHz	FSPL (dB)	Frequency Contribution (dB)
4	44.48	12.08
8	50.50	18.10
12	54.03	21.63
16	56.52	24.12
20	58.46	26.06
24	60.05	27.65
28	61.38	28.98
32	62.54	30.14
36	63.57	31.17
40	64.48	32.08
44	65.31	32.91
48	66.07	33.67
52	66.76	34.36
56	67.41	35.01
60	68.00	35.60
64	68.57	36.17
68	69.09	36.69
72	69.59	37.19
76	70.06	37.66
80	70.50	38.10
84	70.93	38.53
88	71.33	38.93
92	71.72	39.32
96	72.09	39.69
100	72.44	40.04

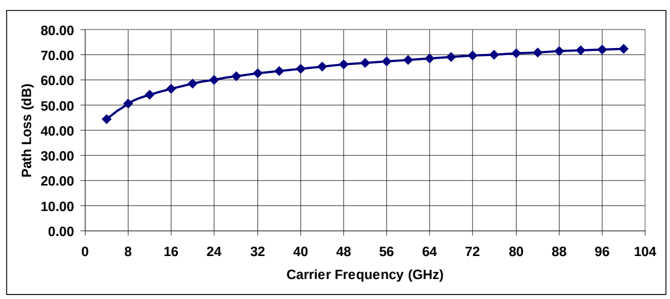

Fig. 1. Free Space Path Loss.

TABLE II. PATH LOSS RESULTS BEAM ALIGNMENT TX-RX

Freq.	**Path Loss (dB) θ1**		**Path Loss (dB) θ2**	
GHz	**200 m**	**300 m**	**200 m**	**300 m**
4	126.9	133.2	126.8	133.0
8	126.1	131.9	126.0	131.7
12	125.7	131.1	125.5	130.9
16	125.3	130.6	125.2	130.4
20	125.1	130.2	124.9	130.0
24	124.9	129.8	124.7	129.6
28	124.7	129.5	124.5	129.3
32	124.5	129.3	124.4	129.1
36	124.4	129.0	124.2	128.9
40	124.3	128.8	124.1	128.7
44	124.2	128.7	124.0	128.5
48	124.1	128.5	123.9	128.3
52	124.0	128.3	123.8	128.2
56	123.9	128.2	123.7	128.0
60	123.8	128.1	123.7	127.9
64	123.8	127.9	123.6	127.8
68	123.7	127.8	123.5	127.6
72	123.6	127.7	123.4	127.5
76	123.6	127.6	123.4	127.4
80	123.5	127.5	123.3	127.3
84	123.4	127.4	123.3	127.2
88	123.4	127.3	123.2	127.2
92	123.3	127.3	123.2	127.1
96	123.3	127.2	123.1	127.0
100	123.2	127.1	123.1	127.0

VI. DISCUSSION AND CONCLUSIONS

From Table I it is clear the contribution of the carrier frequency towards path loss as FSPL increases as a function of frequency, which is expressed by equation (6.1). Fig. 1 shows a plot of FSPL as a function of frequency.

By analyzing the contents of Table II and Fig. 2 and 3, the following is observed:

1) When the beams are aligned, path loss values are lower than when they are not aligned.

2) Path loss values increase with distance and affected mainly by equation (6.2).

3) Path loss values decreases as the carrier frequency increases. This is due mainly to the exponent (n) affecting the shadow fading (SF).

4) Path Loss values for different beams with aligned TX-RX converge to almost same values. This can be explained by referring to equation (6).

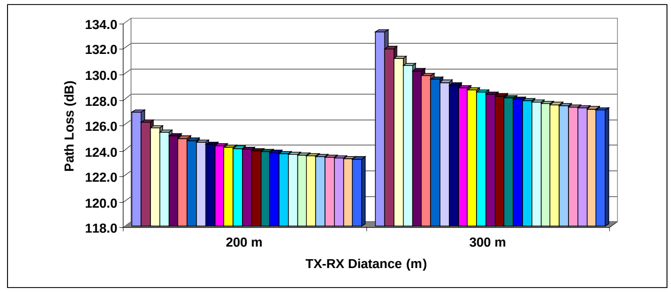

Fig. 2. Path Loss as a Function of Distance and Frequency for Beam aligned θ1.

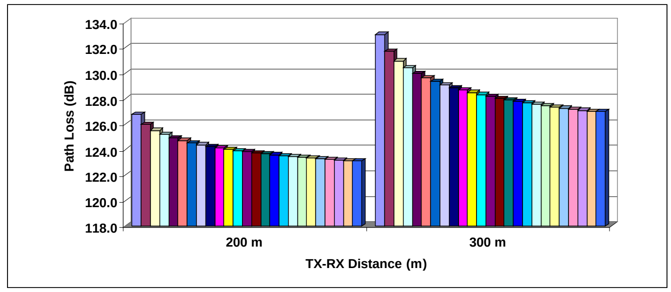

Fig. 3. Path Loss as a Function of Distance and Frequency for Beam aligned θ2.

Thus, all terms in equation (6) should equate as presented in equation. (7). Thus, fulfilling the conditions in a, b, and c below.

$$PL(f,d) = n\alpha(\theta_i) + (\beta(\theta_i) + 32.4) + \chi_\sigma \quad (7)$$

Equal Distance:

$$\beta(\theta_1) = \beta(\theta_2) \quad (7.1)$$

Equal Frequency:

$$\alpha(\theta_1) = \alpha(\theta_2) \quad (7.2)$$

Free Space Path Loss is constant

So, the shadow fading (χ_σ) and the exponent (n) are to equate to support the obtained values in Table II and Fig. 2 and 3.

This indicates that when the beams are not aligned, the two factors that could contribute to higher and different path loss values for equal frequency, distance, and FSPL, are (χ_σ) and exponent (n).

These findings point towards a change in the standard deviation of the shadow fading, which can be expressed by firstly rearranging equation (7) to obtain equation (8).

$$PL(f,d) - (\beta(\theta_i) + 32.4) - n\alpha(\theta_i) = \chi_\sigma \quad (8)$$

Assume that:

$$PL(f,d) - (\beta(\theta_i) + 32.4) = \zeta(\theta_i)$$

Then equation (8) becomes:

$$\zeta - n\alpha(\theta_i) = \chi_\sigma(\theta_i) \quad (9)$$

Now the standard deviation can be defined as:

$$\sigma(\theta_i) = \sqrt{\frac{(\zeta - n\alpha(\theta_i))^2}{M}} = \sqrt{\frac{(\chi_\sigma)^2}{M}} \quad (10)$$

Where;

M: Number of data points obtained during communication.

Table III shows an infinitesimal but constant difference between the presented path loss values corresponding to two differently aligned beams with distance dependence and frequency independence.

From these values, the following is deduced:

1) The presented difference values can be approximated to zero as their dB values are within the approximation and margin errors.

2) Since such values have constant difference irrespective of carrier frequency, it shows that both aligned beams actually converged to almost equal path loss values.

TABLE III. PATH LOSS DIFFERENCE FOR θ1:θI DEGRESS- BEAM ALIGNMENT

Frequency	TX-RX Distance	
GHz	200 m	300 m
4	0.17	0.19
8	0.17	0.19
12	0.17	0.19
16	0.17	0.19
20	0.17	0.19
24	0.17	0.19
28	0.17	0.19
32	0.17	0.19
36	0.17	0.19
40	0.17	0.19
44	0.17	0.19
48	0.17	0.19
52	0.17	0.19
56	0.17	0.19
60	0.17	0.19
64	0.17	0.19
68	0.17	0.19
72	0.17	0.19
76	0.17	0.19
80	0.17	0.19
84	0.17	0.19
88	0.17	0.19
92	0.17	0.19
96	0.17	0.19
100	0.13	0.11

Thus it can be stated with certainty that, when different beams are aligned, they will suffer almost equal path loss under similar conditions, regardless of angle or antenna gain (dBi).

So from equation (9):

$$\frac{d\chi_\sigma(\theta_1)}{d\chi_\sigma(\theta_2)} = 0 \quad (11)$$

From equation (10):

$$\frac{d\sigma(\theta_1)}{d\sigma(\theta_2)} = 0 \quad (12)$$

Where;

θ_1 , θ_2 : Angles of two different antennas having beam alignment.

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A Cyber-Physical Approach to Resilience and Robustness by Design

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***Abstract*—Modern critical infrastructures (e.g. Critical Energy Infrastructures) are increasingly evolving into complex and distributed networks of Cyber-Physical Systems. Although the cyber systems provide great flexibility in the operation of critical infrastructure, it also introduces additional security threats that need to be properly addressed during the design and development phase. In this landscape, resilience and robustness by design are becoming fundamental requirements. In order to achieve that, new approaches and technological solutions have to be developed that guarantee i) the fast incident/attack detection; and ii) the adoption of proper mitigation strategies that ensure the continuity of service from the infrastructure. The "Double Virtualization" emerged recently as a potential strategy/approach to ensure the robust and resilient design and management of critical energy infrastructures based on Cyber-Physical Systems. The presented approach exploits the separation of the virtual capabilities/functionalities of a device from the physical system and/or platform used to run/execute them while allowing to dynamically (re-) configure the system in the presence of predicted and unpredicted incidents/accidents. Internet-based technologies are used for developing and deploying the envisioned approach.**

***Keywords*—Double virtualization; critical energy infrastructures; cyber-physical systems; resilience**

I. Introduction

The evolution of critical infrastructures into complex distributed networks of Cyber-Physical Systems (CPSs) has posed several challenges on how to monitor and control these systems [1]. The physical dimension of hardware components, and the cyber dimension of computations and communications are both susceptible to attacks that could potentially bring down the entire system [2]. This is particularly true in the Critical Energy Infrastructure (CEI) domain, characterized by vast, dispersed and heterogenous infrastructure of assets forming a multifaceted operational environment.

To address these challenges, i.e. to facilitate the monitoring and control of this kind of infrastructures, smart grid concept has evolved. The smart grid deeply relies on the usage of communication and information technologies to enhance the control and monitoring of the grid, while providing a better "awareness" about the state of the grid [3], [4]. As stated in[3], smart grid incorporates several technical initiatives such as Advanced Metering Infrastructure (AMI), Wide-Area Monitoring, Protection and Control (WAMPAC) systems based on Phasor Measurement Units (PMUs) that are aiming to provide the guidelines and guidance on how to collect, transport, use and present data generated by the grid assets. Since these initiatives heavily rely on Information & Communication Technology (ICT) systems and, they are exposing the smart grid to a wide range of security threats and more in general to vulnerabilities that need to be managed to keep the system secure [5]. As a matter of fact, the proliferation of smart devices (and exploitation of cyber advances) can practically enable anyone to gain access and interact with the smart grid supporting infrastructure. As stated in [3], cyber-attacks can take many forms, depending on their objective and goal, while being distributed in location. All these aspects together make it nearly impossible to design and develop a "one-size fits all" approach that guarantees the security for every asset within the infrastructure.

With this in mind, the main purpose of this paper is to present a specific strategy, approach and technological development – the so called "Double Virtualization" (DV) – to enable resilience and robustness of WAMPAC against cyber and physical attacks. Typically, system level control and monitoring functions of a smart grid are deployed in dedicated computational units. Any cyber-physical attacks on these dedicated computational units would compromise the complete operation of the smart grids. To deal with this situation and to minimize the effects of cyber-physical attacks a strategy is proposed that is built on top of cloud computing paradigm and – thus – based on the principle that monitoring and control capabilities/functionalities are logically separated from the hosting computational hardware and/or platform. In such a scenario, it will be possible to dynamically allocate/relocate virtual functionalities/capabilities to other similar computational hardware and/or platform under cyber-physical attacks. The proposed strategy does not contemplate the avoidance of cyber and physical attacks, on the contrary, it focus on their early detection and on defining the mechanisms that ensure continuous operation of a CEI (like the smart grid), by increasing the availability of the control and monitoring functions of the CEI that are re allocated in different hardware under any cyber-physical attacks.

II. Related Works and Supporting Concepts

A. Cyber-Physical Systems and Smart Grids

Nowadays, the conventional systems and processes – in the most disparate context of application e.g. manufacturing, healthcare, automotive, smart grids, logistics etc. and different nature e.g. mechanical, electrical, and chemical – are evolving into CPS. As stated in [6], the term "Cyber-Physical Systems" has been coined in 2006. Today, several definitions of CPS can be found in the literature. According to [7], CPS can be defined as transformative technologies that allow the management of physical assets and computational capabilities of interconnected systems. The definitions in [8], [9], highlight the concept of collaboration and service provisioning. As a matter of fact, CPS are defined as systems of collaborating computational entities that are strictly connected to the surrounding physical assets providing and using services to/from the internet. A working definition for CPS has been offered in [10], where a CPS is defined as a system consisting of computational, communication and control components combined with physical processes. Nowadays, CPSs are the foundation and the key element for smart grids. As a matter of fact, the two major elements of a smart grid are: the supporting infrastructure and the power application. In particular, the former is the one that delivers "smartness" to the grid and concerns with the integration of new technologies (cyber advances) and approaches for enhancing the monitoring and control activities of the operations within the grid. Therefore, Smart grids are opted as the application domain of the presented research, where securing are provisioning them with innovative mechanisms for responding to cyber physical attacks are actually the main objectives.

B. Cyber-Physical Systems and Industry

The research stream on CPS is extremely active and vibrant in the manufacturing domain as confirmed by the number of research activities on the topic. As a matter of fact, there is an extensive literature dealing with the materialization of the CPS vision and related challenges – technical, societal and educational – as confirmed in [11]. Modern production systems and their related control and monitoring solutions can be easily modelled as a network of interconnected and collaborative CPSs where communication takes place constantly both horizontally and vertically. However, the classical heterogeneity in equipment, encompassing distinct functions, form factors, network interfaces and I/O features supported by dissimilar software and hardware platforms is pushing for a new and well-defined strategy to increase the devices interoperability and agility performance [12]. It is necessary to comprehend that today's problem is no longer networking (protocols, connectivity, etc.) nor it is hardware (CPU/memory power is already there, at low-cost and low-power consumption) but rather it is on how to link disparate heterogeneous data sources to the specific needs and interaction forms of applications and platforms. In this scenario, the abstraction and/or virtualization of physical entities in terms of their functionalities – provided as services available over the network – is a necessary condition to ensure the creation of a highly dynamic and evolvable environment while detaching functionalities from the specific runtime, protocols and communication needs as confirmed in [13]–[16]. Furthermore, industrial initiatives such as the Reference Architectural Model for Industry 4.0 (RAMI 4.0) confirms the trend. In particular the Asset Administration Shell concept establishes the guidelines and methodology for industry digitization, i.e. for integrating industrial assets into I4.0 communication backbone [17], [18]. Finally, the research performed by the authors in the manufacturing domain provided the foundation for the design and development of the proposed DV strategy.

C. NIST Framework for Critical Infrastructure Cybersecurity

The NIST Framework for Critical Infrastructure Cybersecurity [19] has been developed to deliver a systematic approach for managing cybersecurity-related risk that is aligned with the typical requirements of critical infrastructure providers [20]. The framework is built around five core concurrent and continuous functions, namely: i) Identify, ii) Protect, iii) Detect, iv) Respond, and v) Recover. These functions together allow organizations to express, in a high-level strategic view, its management of the cybersecurity risk [19]. The NIST framework core elements provided the foundation for framing the application context, developing and implementing the necessary protection and detection mechanisms, as well as, the mitigation actions and recover strategies for robustness and resilience.

D. Wide-Area Monitoring, Protection and Control

The WAMPAC leverages the PMUs and Phasor Data Concentrators (PDCs) to gain real-time awareness of the current state of the smart grid supporting infrastructure and related operations [21]. The WAMPAC can be further divided into three main components, namely: Wide-Area Monitoring Systems (WAMSs), Wide-Area Protection Systems (WAPs), and Wide-Area Control (WAC) [3]. The WAMPAC system provided the environment for the deployment of "Double Virtualization" services. In particular, some services have been developed [22] and later clustered under the name "Double Virtualization" and deployed in already existent WAMPAC to enhance the smart grid supporting infrastructure availability.

E. The Observe-Orient-Decide and Act Pattern

The Observe-Orient-Decide-Act (OODA) pattern (see Fig. 1), introduced by John Boyd[23], is a multi-staged approach to facilitate and speed-up the decision-making process. According to this pattern, the decision-making process occurs in a recurring cycle of four core stages, namely, the observe, orient, decide and act. The main objective is to deliver highly reactive and responsive systems that are capable to continuously adapt and evolve to changing and/or unpredictable circumstances. The OODA cycle has provided the foundation for the design of the overall DV strategy and related processes. In particular, the "Double Virtualization" strategy has been redefined and distilled around this cycle to encompass the OODA four interacting processes:

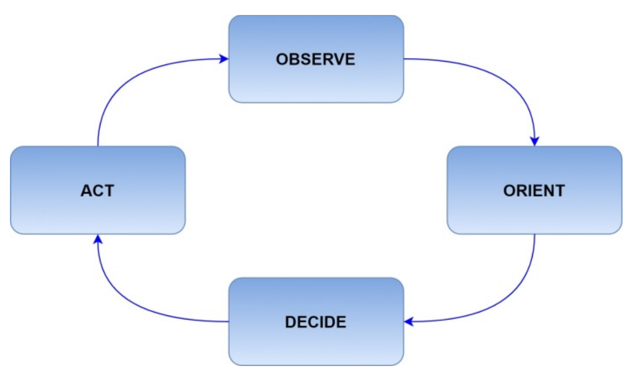

Fig. 1. OODA Simple Loop.

- *Observe:* the stage where related sensorial data is gathered. Data is received from a variety of sources at each moment, which in DV translates to data incoming from all the connected devices.
- *Orient:* DV handles the data to enrich it with meaning that is needed for further inspection: match the data to the respective device, comparison to previous stages, apply inspection algorithms and so on, in order to find meaningful flaws or deviations in the most efficient way. The observations made in this step shape the decisions and actions of the next iterations of the loop.
- *Decide:* the input from the current orientation supplies the model with the possible paths and concludes for the most suitable to deliver (similar to a hypothesis, as referred by Boyd), therefore forming the plan to take into the next step.
- *Act:* The DV system then executes the formerly defined plan, while maintaining track of the advances made and sending information back to observation, thus restarting the loop.

F. Previous Research

Traditionally the power grids have been operated using a centralized automation architecture where in the primary monitoring, control and protection algorithms run at a central server. The SCADA and WAMPAC systems provide the algorithms with the real time measurements and facilitate with the automation systems for real time control. Since the major intelligence for operation of the grid is deployed in a single server, it is always important to ensure continuous availability of the intelligence (algorithms) even under cyber-physical attacks on the device hosting them. Therefore in SUCCESS[1] [24] the concept of Double Virtualization has been introduced. Here DV is designed for virtualizing the monitoring, control and protection algorithms. Furthermore, these virtualized algorithms were moved from one device to another when a specific device hosting the algorithms failed under cyber-physical attacks. A proof of concept implementation was then done based on CALVIN[2] Internet-of-Things (IoT) platform and presented in [22]. The study showed that CALVIN was a suitable platform for DV and that with DV the availability of the key automation functions was improved. However, usage of CALVIN confined the implementation of such automation functions to its own language, thus demanding considerable time to learn how to integrate them in its framework. Moreover, CALVIN does not provide an easy way to execute and control external computational processes, such as scripts or even the simple execution of terminal emulators, and it was found that CALVIN lacks on offering flexibility, security and scalability to larger systems and heavier functions.

III. System Model and Problem Formulation

A. WAMPAC Architecture

Fig. 2 shows a typical hierarchical WAMPAC architecture and communication layout together with the distinct computer layers ("cloud", "fog", "edge" and "device"). The state of the system is measured by PMUs. PMU measurements are collected and communicated to devices within the upper hierarchical levels of the architecture – called Phasor Data Concentrators (PDCs) –through high speed communication links (based on the IEEE C37.118.2 [25] standard for synchrophasor data transfer for power systems) to produce a real-time, time-aligned output data stream. PDCs can exchange phasor data with others PDCs. Finally, collected data are communicated to the WAMPAC control center where several potential applications are executed such as state estimation, model validation, early warning systems, etc.

The networked and wide distribution nature of the WAMPAC architecture opens the doors to several vulnerabilities and/or possibility for cyber-attacks that can potentially affect the normal functioning of the system. It is necessary to design, develop and implement appropriate countermeasures to ensure the early detection and localization of those attacks while minimizing their impact on the system.

B. Cyber Attack Classification, Vulnerabilities and Entry Points in WAMPAC

The cyber-physical nature of a WAMPAC-based system implies that cyber-attacks can be easily directed to both power/physical and communication resources. Taking into account the WAMPAC environment, there are several relevant threats where the "Double Virtualization" approach/strategy can be applied as countermeasure, and that can be clustered according to [3] into three main groups, namely: i) Time-based attacks; ii) Integrity attacks; and iii) Reply attacks. However, in the context of the present research only time-based attacks have been considered, i.e. detectors have been implemented and "Double Virtualization" has been applied as a special measure to enhance availability and resilience of grid monitoring and control applications.

In a time-based attack, the attacker tries to compromise the normal conditions and/or operations of the system by making a device, resource or service unavailable over the network. An example of this is the Denial of Service (DoS) attack.

The DoS exploits communication vulnerabilities of CPS to inject false data with the objective of over-flooding the network. Furthermore, devices themselves are vulnerable to physical damage by malicious and/or accidental causes that can lead to the loss of all the critical data provided by that channel.

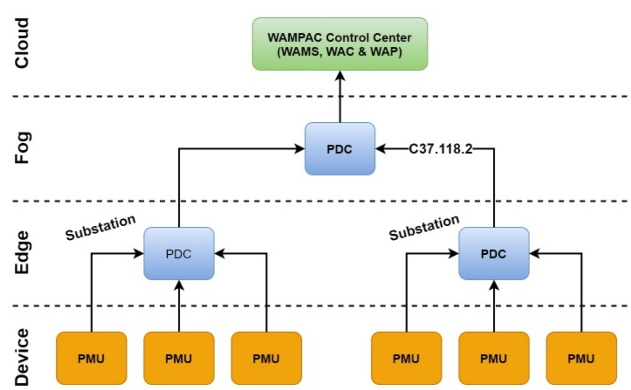

Fig. 2. Typical WAMPAC Architecture.

[1] https://success-energy.eu/
[2] https://www.github.com/EricssonResearch/calvin-base

As stated in [26], for each identified threat it is possible to model and identify an attack surface (see Fig. 3) with related multiple entry points. The attack surface allows to highlight the penetrable boundaries – i.e. the boundaries that an attacker can use to connect with – of the system under study as well as the internal path to critical resources. In the case of CPS entry points translate to: i) physical connections like cables, power sockets, etc., and ii) cyber connections like global accessible APIs, communication sockets, open ports, etc. These are also the boundaries that have been considered in the present work (see the yellow boxes in Fig. 3) as possible vulnerabilities and entry points that need to be properly handled by providing a strategy that allows monitoring and control functionalities to remain available even if devices are compromised in both physically and cyber dimensions.

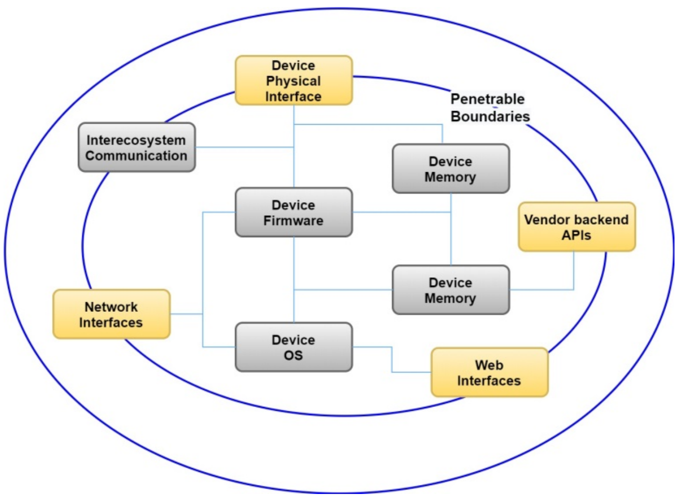

Fig. 3. Attack Surface, and Considered Entry Points, Adapted from [26].

IV. Implementation of Double Virtualization

A. Necessary Technologies for Double Virtualization

1) Node-RED: The implementation of DV presented in this publication is supported by Node-RED [3] framework. Node-RED is a flow-based programming tool oriented to development of IoT applications, which provides an easy-to-use browser-based graphical editor. Node-RED supplies a wide set of core Nodes, and possesses a big and highly active community that contributes with free-of-charge custom nodes.

Furthermore, the panoply of exisitng features and nodes on Node-RED enable it to easily access terminal emulators, and therefore execute and manage running processes of the host machine. On the other hand, it also provides the development environment to establish connections to the running applications and processes, while also enabling their functionality extension as part of the embedded logic. This is one of the main reasons why this technology has been opted as the development and deployment framework for DV. Altogether, Node-RED has the potential to offer connectivity of several devices, by creating APIs and services supported on crossover environenments, using varied protocols and which can be easily deployed in its runtime.

2) PM2: PM2[4] is an advanced process manager oriented to Node.js applications, however, it has also the capability of managing other types of processes such as Bash or Python scripts and can be easily invoked by either the command line prompt or by embedding in any Node.js application such as Node-RED.

B. Double Virtualization Architecture

To integrate DV functionality and logic within an ordinary WAMPAC architecture and configuration, several components and related functionalities and interfaces have been designed and implemented. These functionalities have been deployed using the existing WAMPAC infrastructure, i.e. WAMPAC device platform, to equip current devices with the necessary logic for DV and to create two type of devices, namely:

1) DV asset device: devices where the application layer, i.e. all the application running on the them, is/are virtualized in order to be easily managed by the DV components and logic (see Fig. 4); and.

2) DV administration and management (DVA and M) device (see Fig. 5): devices that are logically settled at a higher level than the DV Asset devices and that are intended to run, manage and initiate the whole DV process by extracting, collecting and processing data provided by the DV Asset devices, in real time, as well as to execute the necessary actions according to the result of the data processing task.

Both *DV Asset* and *DVA&M* devices are necessary for *DV*, i.e. the *DV* process and functionalities emerge as the result of the communication and interaction between these two types of devices.

The research presented in this paper is intended to spotlight the *DV* concept and functionality by providing an example of application where *DV Asset* and *DVA&M* devices are used to deliver to WAMPAC system the capability of:

1) detecting failures that compromise the availability of *DV Asset* devices; and

2) mitigating detected failures to minimize their impact on the system.

According to these objectives the architecture and system configuration presented in Fig. 6 have been implemented where a single *DVA&M* device and several *DV Asset* devices are employed to provide the necessary results.

C. DV Asset device

The *DV Asset* devices provide the following functionalities and/or services:

- *Virtualization service*: it includes all the necessary mechanisms to enable the virtualization of device applications. Thus, it is responsible to create an abstraction layer that allows to separate device hosted applications from the specific hardware architecture while allowing these applications to be moved easily moved and interpreted by other *DV Asset* devices.

[3] https://nodered.org/

[4] https://pm2.keymetrics.io/

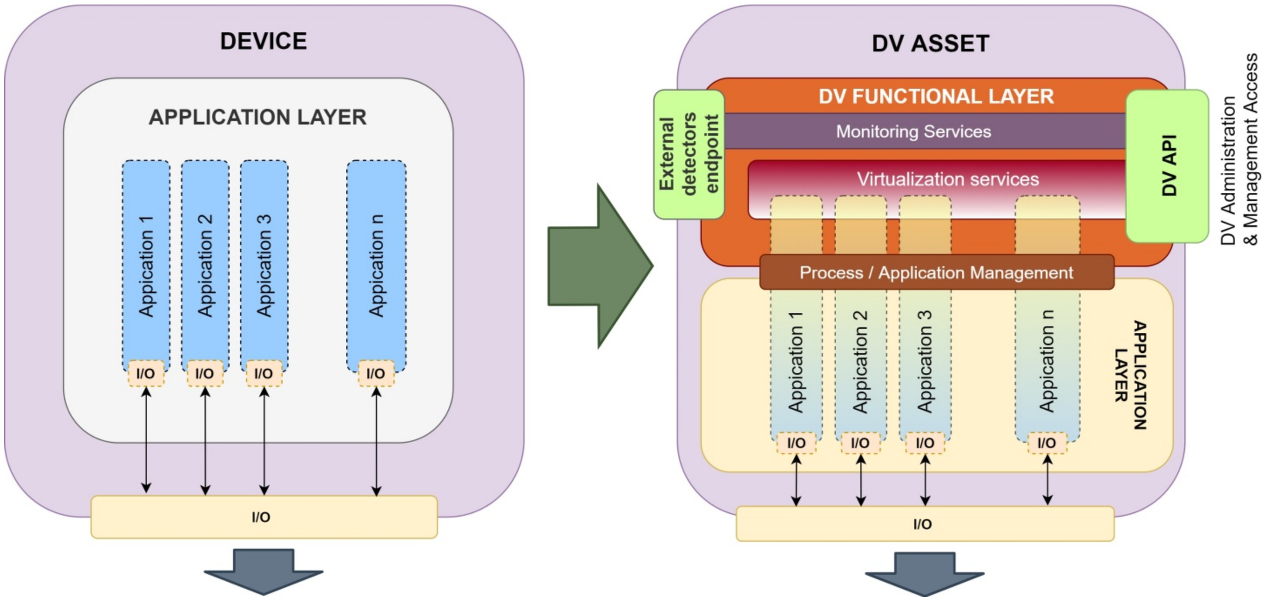

Fig. 4. Computational Device “Enhanced” as DV Asset Device.

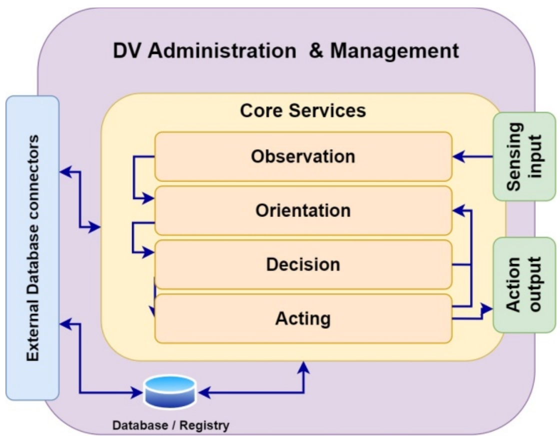

Fig. 5. DV Administration and Management Device.

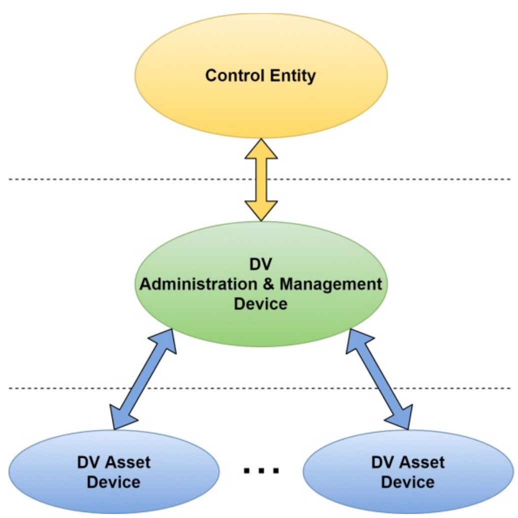

Fig. 6. DV Architecture with a Single DVA and M Device.

- *DV API*: it is an endpoint specifically created to allow *DVA&M* devices to remotely access the *DV Asset* devices for extracting and collecting the necessary information as well as for sending commands for triggering specific *DV* routines and actions (e.g. start, stop, reconfigure and/or move virtualized functions from one *DV Asset* to another).

- *Monitoring service*: it provides the ability to the *DV Asset* device gather all the necessary information about the resources attached to it and related functionalities. Some gathered information include: network connection status, CPU and memory usage, as well as any change in the virtualized functions. As part of the Monitoring service there are: *Heartbeat Service* and *Ping Service*. Furthermore, Simple Network Management Protocol (SNMP) services could also be included to enable deeper monitoring capability of the *DV Asset* device.

D. DV Administration and Management device

The *DVA&M* device is then structured to comply with the OODA loop as a way to fulfill the goals proposed by the DV, and adopting the “enhanced” system with the Control loop depicted in Fig. 7. So, the *DVA&M* devices are provided with the following functionalities and/or services:

- *Persistence Service*: it is a necessary condition for DV to have some type of database system for supporting registry functionality (e.g. register available *DV Asset* devices), as well as, storing temporary data necessary to run the *DV* logic. This service can be as simple as a file system or a more complex DB framework, either locally or remotely:

- *DVA&M Core*: combination of the DV resources and functionalities that constantly uses the available set of information provided by the *DV Asset* devices and any other external data source if needed. The core features of the *DVA&M* have been divided in four distinct stages, namely:

1) Observing: The DV acquires data from connected devices installed on the sub-station through several pre-defined connectors. The data can be obtained by using request/reply (e.g. Heartbeat, as used in the current implementation) or publish/subscription, or through the integration of connectors which may be implemented to cope with several protocols, as for example, REST endpoints. Also, the sources of data are mainly composed by the *DV Asset* devices working in the subsystem under the supervision of the *DVA&M* device, however, it has also been implemented connectors that enabled the integration of external detectors, which by their turn, also send data related to *DV Assets* devices.

2) Orienting: In this stage, each item of the received data is inspected through certain mechanisms, in order to be contextualized in respect to the system, so that possible scenarios can be envisioned. This means that for each incoming message, the content is deciphered in order to identify the source device and the type of information, compare it with previous stage, look for mismatching or unexpected values, and so on. This enables to identify if and which algorithms of the DV can possibly make use of the information to take some action. Through the help of dedicated observation services, sometimes it is easy for the DV to identify the type and source of the data. For example, receiving successful or failed heartbeat messages on dedicated HTTP(s) request will rapidly lead the DV to change the possible future scenario to take in consideration.

3) Decision: The data and information provided by the *Orientation* stage are used during this stage by the *DVA&M* device to decide about DV actions, i.e. decisions computed during this stage are then translated into actions to be executed in the *Acting* stage. Moreover, decisions are made through algorithms that possess a configurable set of rules, limits and thresholds. Considering the former heartbeat example, depending on the configuration in use in the system, one failure message may be enough to activate a mitigation action, while on other system is may be needed two consecutive heartbeat failure messages. In the end of the stage, the possible decisions are: “no action”, or “start migration” to trigger the execution of a mitigation action that involves at least two *DV Asset* devices. The actors of the decision are also established during this stage.

4) Acting: It is the practical execution of the decisions of the *Decision* stage, i.e. the decisions taken by the *DVA&M* device are translated into an action to take effect on *DV Asset* devices, if necessary. This is accomplished by establishing dedicated channels, which were designed as part of the DV communication and management features, for sending the necessary information and control data required by the involved *DV Asset* devices to execute the actions. Moreover, while actions are being deployed, the *DVA&M* device continuously observes the status of the operations while providing this information as internal feedback to the loop.

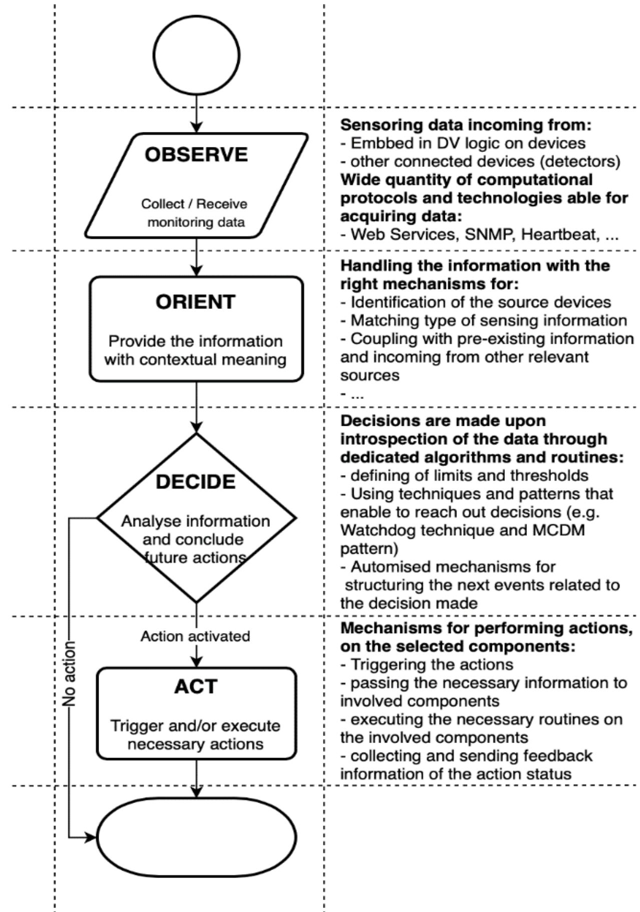

Fig. 7. DV Control Flow Loop.

V. Application Scenario and Results

A. Exemplary Application Scenario

A simple exemplary application scenario that involves the execution of a mitigation action – Migration – is described to show the potential of DV strategy. The scenario includes the following stages:

a) Monitoring of DV Asset devices connectivity and detection of a connectivity.

b) Deciding about the detected status of the *DV Asset* device, i.e. identify the best action to be taken (migration in the example) as well as the involved actors.

c) Acting: the *DV&AM* device triggers the action by sending information to the involved *DV Asset* devices, while these execute the action according to the information received.

The system configuration is based on the System Model presented in Section III, where PDC devices are connected to PMU devices that – in turn – are connected to a Real Time Digital Simulator (RTDS) to deliver measurement data to the PDC. PDC executes internal applications (simulation scripts) for collecting and processing data from the PMUs and data provisioning to the Control Center. All these components together represent a substation (Fig. 8).

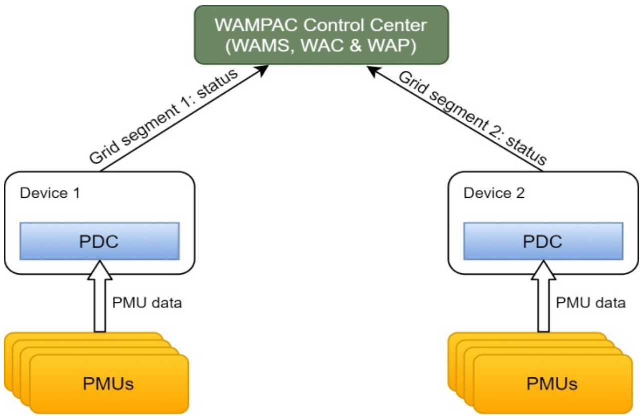

Fig. 8. Simple Grid Monitoring use-case using PMU Measurements.

In this scenario, PDC devices are "enhanced" with DV logic in order to act as *DV Asset* devices. Next to the PDC a *DVA&M* device is added to monitor and act on the *DV Asset* devices. At this point the initialization of the system can take place and *DV Asset* device applications and/or virtualized functionalities are communicated to the *DVA&M* together with connections details to enable the execution of the *Monitoring services (*Watchdog and Heartbeat services). A third *DV Asset* device is also included and used as "supporting" device during the execution of the migration action (see Fig. 9). Once initialized and all the conditions are settled, the DV logic can take place.

Conceptually the OODA loop is executed by the overall system. In particular, the *Observation* stage runs with the *DV Asset* devices (i.e. "enhanced" PDC) that use the internal *Heartbeat* service to communicate their connectivity status. The status is monitored by the *DVA&M* device that in turn uses the *Watchdog* internal service for detecting any connectivity failure of the related *DV Asset* devices. At some point in time a connectivity failure (connection timeouts, communication delays, etc.) of a specific *DV Asset* device is detected by the *DVA&M* device, the *Decision* stage can start. During this stage, the *DVA&M* is responsible for deciding the most suitable mitigation action and, in particular, to start the migration process which involves the following steps:

1) Identification of the best suitable *DV Asset* device that can host the virtualized functions of the faulty *DV Asset* device;

2) Move the virtualized functions of the faulty *DV Asset* device to the new selected *DV Asset* device; and.

3) Track the migration process while keeping updated the tasks of the *Observation* stage.

In the current scenario the system configuration evolves from the one depicted in Fig. 9 to a newer configuration (see Fig. 10), where the "supporting" *DV Asset* device is now running the virtualized functionalities of the faulty *DV Asset* device, i.e. it shows the same behavior of the faulty *DV Asset* device.

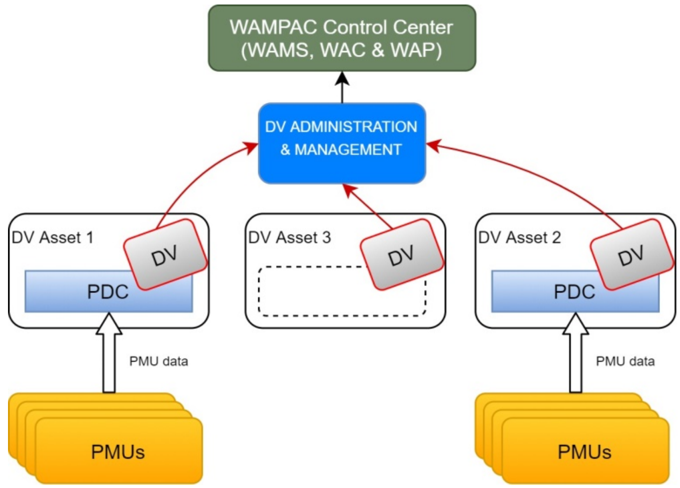

Fig. 9. Grid Monitoring use-case using PMU Measurements with DV Components Integrated.

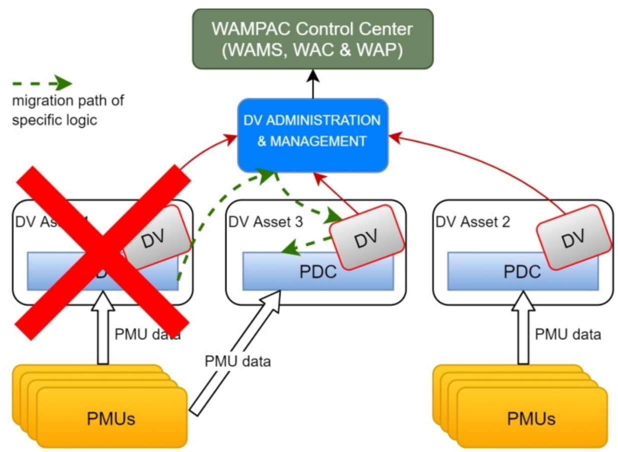

Fig. 10. System State after Migration Process Triggered by a Faulty Connection.

B. Results and Discussion

To measure and quantify the impact DV strategy has in the normal operation of the system the following metrics are considered:

- The time instant a connectivity failure is detected by the *DVA&M* device by using the internal *Watchdog* service.
- The time instant a decision is taken by the *DVA&M* device, i.e. a suitable *DV Asset* device is identified and all the virtualized functions of the faulty device are ready to be moved.
- The time instant the action is practically executed by the *DVA&M* device, i.e. the *DVA&M* device connects to the selected *DV Asset* device (through the *DV API*) and send the virtualized functions and configurations.
- The time instant the action is concluded, i.e. when a notification is received by the *DV Asset* device.

These time instants are shown in Table I, where each row identifies the execution of a migration action.

TABLE I. TIMESTAMPS RELATED TO THE DV AND AM MITIGATIN PROCESS

detection	decision	action	mitigation end
1578421500738	1578421500740	1578421500744	1578421501216
1578422203744	1578422203746	1578422203750	1578422204211
1578422358906	1578422358907	1578422358912	1578422359369
1578423527297	1578423527298	1578423527301	1578423527758
1578423642621	1578423642624	1578423642627	1578423643088
1578423779547	1578423779547	1578423779549	1578423779906
1578423886704	1578423886705	1578423886709	1578423887170
1578424038372	1578424038374	1578424038377	1578424038842
1578424374310	1578424374312	1578424374316	1578424374779
1578424506782	1578424506783	1578424506789	1578424507247

From the values of Table I, it is possible to determine the time consumed on the distinct stages, once a failure is detected (i.e. decision, action preparation and execution times), as well as, the total time consumed, from the detection to the end of the mitigation action. These times are shown in Table II.

The values show an extremely reactive system, where the decision and action preparation times are less than 10ms. On the contrary the action execution time is where the system consumes most of the total time. This time consumed is mainly due to the technological constrains (REST connections and implemented interaction protocols). However, the total time needed for a complex mitigation action is still on the order of milliseconds. Finally, during the execution of a mitigation action (in the example migration) there is always some data that is lost. This loss of data is directly related to the time needed for executing the mitigation action (in the example the mean time of 457ms as shown in Table II). It is possible to quantify the loss of data too by considering that PMUs devices publish measurements each 20ms or in other words with a 50 frames per second rate. Therefore, by capturing the time instant of the last data frame received by the *DV Asset* device before the connectivity fault and the time instant of the first data frame after the migration action is executed the loss of data can be estimated (see Table III).

TABLE II. TIME CONSUMED BY DVA AND M DEVICE DURING MIGRATION

	Decision time (ms)	**Action preparation time (ms)**	**Action Execution time (ms)**	**Total time (ms)**
	2	4	472	478
	2	4	461	467
	1	5	457	463
	1	3	457	461
	3	3	461	467
	0	2	357	359
	1	4	461	466
	2	3	465	470
	2	4	463	469
	1	6	458	465
Mean	2	4	451	**457**

TABLE III. TIME ELAPSED OF DATA FRAMES ACQUIRED BETWEEN FAULTY AND NEW DEVICE

	timestamp from last frame before fault	**Timestamp from first frame after migration**	**time lapse (ms)**	**lost frames**
	1578421501400	1578421500540	860	43
	1578422204400	1578422203600	800	40
	1578422359560	1578422358700	860	43
	1578423527940	1578423527100	840	42
	1578423643280	1578423642480	800	40
	1578423780100	1578423779320	780	39
	1578423887360	1578423886540	820	41
	1578424039000	1578424038200	800	40
	1578424374960	1578424374100	860	43
	1578424507420	1578424506620	800	40
Mean			**822**	**41**

Finally, in Table IV, the approximated time consumed during the deployment, initialization, and configuration of the migrated functionalities in the new *DV Asset* device is given. This time is calculated by correlating the values gathered from the previous tables.

TABLE IV. APPROXIMATION OF *DV ASSET* DEVICE TIME ELAPSED WHILE LAUNCHING FLOWS AND INITIALIZING THE APPLICATION SCRIPTS

	Migration duration on DVA&M (ms)	**Time elapsed of lost frames (ms)**	**Approximated time of processing and initializing received flows on the *DV Asset* device (ms)**
	478	860	382
	467	800	333
	463	860	397
	461	840	379
	467	800	333
	359	780	421
	466	820	354
	470	800	330
	469	860	391
	465	800	335
Mean	457	822	**366**

The approximated time of processing and initializing flows on the DV Asset device strictly depends on the technology chosen and on technological constraints (such as type of communication channels and interaction protocols), and, thus, this is the first parameter the authors are working on for DV strategy performance improvement.

VI. CONCLUSIONS AND FUTURE DEVELOPMENTS

In this paper the authors analyzed the importance of WAMPAC to gain a real-time awareness of the current state of the smart grid while ensuring the correct operation. Securing WAMPAC is – thus – a key priority. In this landscape, the authors presented a new and improved technological environment for developing and deploying the novel approach/strategy – i.e. “Double Virtualization” – to ensure the robust and resilient design and management of critical energy infrastructures based on CPSs. The proposed approach/strategy deeply relies on current trends in internet technologies and advanced computing technique where virtualization of the resources is demanded. Furthermore, the evolution of current systems and processes into networks of CPS, and the related separation between "cyber" and "physical" dimensions creates the foundations for "Double Virtualization". As a matter of fact, this separation allows the creation of a highly dynamic and evolvable environment where functionalities (that lives in the "cyber" dimension) are detached from the specific runtime, protocols and communication needs. By appropriately exposing WAMPAC physical devices (PDCs) in terms of their functionalities it is possible to migrate functionalities from one device to another in the presence of cyber-attacks. Finally, the paper provides an exemplary application scenario to validate the proposed approach/strategy while summarizing how cyber-attacks on WAMPAC can trigger mitigation actions consisting in the migration of the functionalities from one runtime to another. However, further experiments need to be conducted to optimize the "Double Virtualization" i.e. optimization of the mitigation strategies, new monitoring algorithms for detecting abnormal behaviors and cyber-attacks within WAMPAC, integration of multi-criteria decision making (MCDM) algorithms to expand and improve decision agility, and investigate a distributed management strategy to handle any failure of the DVA&M component.

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Text Messages: A Computer-Mediated Discourse Analysis

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Abstract—This study explores the discourse of text messages from a microlinguistic perspective by means of concordance analysis. It aims at sorting the dominant phonological, lexical and grammatical features that mark texting as a peculiar asynchronous mode of computer-mediated communication. Also, it investigates how technology reshapes texters' linguistic habits as long as spatio-temporal constraints are imposed. The study goes beyond the description of linguistic features as it takes at its core the explanation of the functions performed by each of these features. Findings showed that most of the phonological, lexical and grammatical features of the discourse of text messages were consciously employed to save space and to speed up communication. Furthermore, the study demonstrated that though the discourse of text messages is space-bound and visually decontextualized, it proved to be cohesive, adaptable and interactive in order to perform common language functions such as greetings, expressing attitudes, congratulations, showing involvement, asking for information and demonstrating social solidarity. Finally, based on textual evidence, findings showed that texters created a set of orthographical surrogates to recompense the absence of verbal and para-verbal cues due to specific technological affordances.

Keywords—Text messages; computer-mediated communication; discourse; technological affordances

I. Introduction

Communication refers to the exchange of thoughts, opinions or information through spoken, written or signed forms of language. Electronic gadgets have developed a distinct medium of communication, known as computer-mediated communication (CMC for short), with peculiar micro- and macrolinguistic features. CMC is generally viewed as a computer-based human-to-human communication in particular contexts shaping and reshaping media for various purposes [1]. That is, "the more people chat, text, email, blog … etc. on the Internet from different cultures, the more homogenised language may become" [2]. In addition to the spoken and written forms of language, such developing electronic medium is claimed to constitute a third modality [3]. In an electronic environment, an individual is surmised to be linguistically and communicatively competent if he manages to translate much of the written text and emotext (i.e. informal language codes used by communicators to mark up their messages and convey affective and socio-emotional information) into sounds. Simultaneously, he is expected to able to render his talk into peculiar orthographical forms. In so doing, he is acknowledged as a member of an online discourse community.

Indeed, the way technologies affect language has motivated considerable speculation and inspired scholars in a plethora of research areas, including linguistics. It is reported that one influential feature of CMC environments is the evolution of a new discursive world with a new cultural context yielding peculiar discourse properties [4]. Although each of CMC modes, including text messages, blogs, wikis, and social media platforms, manages to communicate the intended message, they differ –both qualitatively and quantitatively –in respect of their dominant linguistic features. Hence, the present study seeks to provide a qualitative microlinguistic analysis of the discourse of text messages on the phonological, lexical and grammatical levels. Each distinct linguistic feature is paradigmatically assumed to communicate a specific discourse function. It is noteworthy that the present study focuses on English texting as English is undoubtedly the lingua franca of all modes of online communication [3, 5, 6]. Moreover, as claimed in [7], though there is a growing academic interest in texting, a few in-depth studies has been conducted to describe the language used. Existing work on the discourse of text messages is confined to superficial description of the amalgamation of the common features of spoken and written languages that finally helped with the emergence of a new medium of communication. One more limitation of available literature on the language of text messages is that most studies do not tackle the communicative functions that the gamut of subtle linguistic features of texting perform. Hence, the present study is planned to fill in this gap by offering a comprehensive description of the linguistic features of text messages with special reference to the communicative functions they generally perform in everyday interaction among adult texters.

Any analysis of online behavior that is grounded in empirical, textual observations is known as computer-mediated discourse analysis (henceforth CMDA) [8]. A good question in CMD research should be empirically answerable and textually motivated. Also, it should be ostensibly interesting to the research community, and therefore it is advised to be motivated by a hypothesis, and open-ended [8]. In view of these guidelines, the questions of the current study can be stated as follows: (1) what are the key phonological, lexical and grammatical features of the discourse of text messages? And (2) what are the functions performed by each of these features. Answers to these questions shall fulfill a three-fold objective. First, it demonstrates that despite differences in language production conditions, synchronicity level and the medium used, the discourse of text messages displays certain linguistic features that would render it as a distinct mode of communication. Second, it explains that CMC differs from face-to-face (FTF) communication, not only because of lack of non-verbal cues, but also as a result of ever-changing technologies. Finally, it analyzes the functions fulfilled by the gamut of the linguistic features remarkable of the discourse of text messages.

Though the present study assumes that the discourse of text messages would display particular linguistic features due to the technological affordances imposed on the creation of a text message, it is also hypothesized that such features would be similar to those marking other CMC modes. Furthermore, it is assumed that the same discourse function would be fulfilled by different linguistic features on the phonological, lexical and grammatical levels.

The reminder of this paper is divided as follows. Section II is a survey of related research on the discourse of text messages. Section III offers the theoretical preliminaries upon which the current study is based. Section IV explains the methodology in terms of the procedures of data collection and data analysis. Section V is a qualitative analysis of the data. Section VI discusses findings and offers insights for further research.

II. Literature Review

Digital technology has remarkably caused drastic changes and raised doubts concerning the language of human-human and human-computer communications. However, descriptions of the technologies, functionalities and frameworks of CMC are likely to be outdated by the time they are published due the evolutionary nature of most CMC modes. The rapid growth of the number of text messages all over the globe generated a considerable number of linguistic issues. More specifically, the discourse features of such mode are ostensibly under-researched. Most of the studies that were concerned with the discourse of text messages adopted different microlinguistic and macrolinguistic approaches [7, 9-16]. That is, they analyzed the discourse of text messages from the phonological level up to the pragmatic level. However, as the following review would demonstrate, none of these studies was particularly concerned with the functions that each linguistic feature performs in the course of texting.

Thurlow and Brown [9] conducted a discursive analysis of 544 text messages written by teenagers. Serving the sociolinguistic Grecian maxims of (a) brevity and speed, (b) paralinguistic restitution and (c) phonological approximation, messages were both linguistically unmarked, but communicatively adept. Findings showed that the average length of text messages was about 14 words (with an average of 65 characters). The most frequent linguistic forms highlighted in the data included (a) shortenings, contractions, and clippings, (b) acronyms and initialisms, (c) letter/number homophones, (d) typos and non-conventional spellings, and (e) accent stylizations.

Bush [10] was much concerned with the way abbreviations in text messaging change written discourse. The study classified such abbreviations into nine separate semantic categories: homophonic single grapheme (e.g. 'n' for 'and'), numeric (e.g. 'a3' for 'anytime, anyplace, and anywhere'), aphesis/abbreviation (e.g. '@coll' for 'at college'), dropping vowel (e.g. 'fwd' for 'forward'), acronyms (e.g. 'gol' for 'giggling out loud'), alphanumeric (e.g. 'dem&' for 'demand'), grapheme changes (e.g. 'ezi' for 'easy'), abbreviated phrase (e.g. 'Ic**wenuxme' for 'I see stars when you kiss me') and contractions (e.g. 'wassup' for 'what’s up').

Bieswanger [11] conducted a contrastive analysis of different shortening strategies in English and German, represented by 201 and 387 text messages respectively. The analysis was much concerned with lexical reductions that were listed into six classes: initialisms, clippings, contractions, letter-number homophones, phonetic spellings and word-value character. Findings showed that English generally use more shortenings, contractions and phonetic spellings than German.

Ling and Baron [12] compared text messages and instant messages produced by American college female students. The corpus consisted of 191 messages, comprising 1473 words. The analysis targeted message length, emoticons, lexical shortenings and sentential punctuation. Text messages averaged 7.7 words. The salient linguistic properties were emoticons, acronyms (e.g. 'ttyl' for 'talk to you later'), abbreviations (e.g. 'R' for 'are'), and vowel deletion (e.g. 'ovr' for 'over').

Rafi [13] tested the morpho-syntactic and lexical choices made by males and females Pakistani texters. Findings highlighted the use of abbreviations (e.g. 'y' for 'why') and shortening (e.g. 'n' for 'and'). At lexical level, texters used meaningful condensed forms (e.g. 'intro' for 'introduction'). Also, there was a significant gender-based difference in the number of words per a text message, the complexity of the messages and the use of punctuation. Similarly, Plester and Wood [14] focused on preteen British children’s use of text messaging, particularly the use of abbreviations. Findings showed that the most frequent linguistic features were rebus spelling, letter/number homophones, phonological reductions, symbols and accent stylization.

By means of WordSmith software, Tagg [7] used a corpus of 11.000 text messages to explore their defining linguistic features that differentiate them from spoken interaction. Findings showed that text messages are marked by colloquial and regiolectal contractions, spelling variation, misspellings and respellings, speech-like ellipsis, excessive use of headers and tails, visual morphemes, and puns and word playing. Unlike Tagg [7], Thurlow and Poff [15] were much pragmatically oriented as they approached text messaging as a pragmatic phenomenon. They adapted the Gricean maxims of quantity, quality, manner, and clarity to the designation of three maxims peculiar to the language of texting: brevity and speed, paralinguistic restitution, and phonological approximation. The maxim of brevity and speed was manifested in the abbreviation of lexical items and the minimal use of capitalization and standard punctuation. Likewise, the maxims of paralinguistic restitution, and phonological approximation highlighted the absence of prosodic features such as stress and intonation.

McSweeney [16] investigated the functions performed by text messages exchanged by bilingual communicators. Based on a large corpus of text messages, the study highlighted how texters change the conventions of orthography into emoji and digital stickers. The most crucial functions performed by text messages were to express specific societal relationships, underlie politeness markers, express aspects of identity, and highlight implied information. In addition to these functions, the study offered an all-inclusive account of the linguistic features of text messages, including abbreviations, emojis and emoticons, differentiating between their literal meaning and pragmatic meaning. For instance, while 'lol' stands for 'laugh out loud', it is meant to belittle, mock, or ridicule an addressee.

To recap then, it is obvious that most of the studies that approached the discourse of text messages focused more on the lexical features rather than other microlinguistic features. Also, the functions of these features were not clearly stated. Hence, the present study sets out to fill in this gap by offering a full account of the phonological, lexical and grammatical features of the discourse of text messages and highlighting their functions that are unquestionably situationally motivated.

III. Theoretical Preliminaries

A. Computer-Mediated Communication

The term 'computer-mediated communication' (CMC) emerged in the 1980s as an umbrella term covering a range of modes used for communicating online, including e-mail, chat systems, video conferencing, instant messages, blogs, wikis, etc. Unlike FTF communication, CMC lacks common non-verbal cues such as facial expressions, eye contact and gestures. Also, the auditory channel is deactivated and feedback is either absent or lagging. It has been likened to speech, and to writing, and considered to be both and neither simultaneously.

CMC modes are claimed to support scholarly activities and research, personal and group communication, discussion, play and learning, dissemination and retrieval of information [17]. Also, they engage users in purposeful exchanges of information, opinions and interests with other humans, and offer second language learners a chance to enhance their learning experience [4]. Moreover, CMC modes productively augment human identity and community [18], and enable health professionals and care teams to document and disseminate information instantly and effectively [19]. Finally, they are claimed to provide learning environments that support constructivist approaches to learning [20], and to represent an effective instructional tool for pragmatic instruction [21].

The most common classification of CMC modes is based on synchronicity. On the one hand, synchronous CMC is like spoken interaction [21] as it is produced when communication occurs between two or more users who join an ongoing conversation in real time, e.g. chat systems. Newhagen and Rafaeli [22] distinguishes six special features for synchronous CMC: multimodality, hypertextuality, packet switching, synchronicity and interactivity. On the other hand, asynchronous CMC is not simultaneous as there is a time gap between message transmission and reception so that users can read and re-read them to give a more thoughtful answer as in the case of text messaging that is mostly based on one-to-one, text-based, two-way transmission of messages. Synchronous and asynchronous CMC modes cannot be sharply distinguished, and therefore should be distributed on a continuum ranging from the highly synchronous to the highly asynchronous [6].

The following section discusses how the properties and technological affordances characteristic of CMC modes are realized in the mode of text messaging in addition to the restrictions affecting language production via such mode.

B. Text Messages

Text messages (also known 'SMS' and 'texting') are one of the most popular and pervasive applications of mobile phones. Text messaging has seen phenomenal growth since the late 1990s. What makes it ubiquitous is that it is cheap, personal and unobtrusive. However, one should mark the interplay between what technology affords and what communicators bring to technology itself [15]. Commenting on the problems that a person might encounter when text messaging, it is claimed that such problems are related to (a) understanding evolving language as text messages have their specialized language, (b) determining intent from content, and (c) mis-addressing messages [23].

Text messages perform various functions. They foster all kinds of social relationships, e.g. sympathizing, requesting for a call, reflecting the time of the day, sharing interests, exchanging personal news and gossip, greeting, offering help and advice, grooming, and circulating jokes, riddles and remarks [24]. Also, they are used to arrange and adjust times to talk, coordinate with friends and family, gossip and chat [23], demonstrate one's involvement in a social network, and vote in electoral campaigns [15, 25].

The language of text messages is referred to as 'textese' and 'texting'. Textese or texting is approached as a multidisciplinary field of CMC that explores mobile and computer-mediated media and their impact on communication, social practices, and information dissemination and exchange [7]. Later, the term 'celllinguistics' evolved to refer to this area [24]. Such language used in texting is found to include extensive use of abbreviations and acronyms, elision of vowels, use of emoticons, and incomplete syntactic structures, minimal use of punctuation marks, respellings and untraditional openings and closures. Much of these linguistic features are ascribed to the technical constraints of texting as well as the existence of common background knowledge among texters.

C. Computer-Mediated Discourse Analysis

Discourse simply refers to any stretch of spoken or written language with particular features performing a set of functions that shape social practices. It covers both linguistic and non-linguistic meaning-making. Electronic gadgets are claimed to alter discourse conventions, adding a new electronic element to language [26]. Studies on the reproduced language of CMC use the term 'computer-mediated discourse' (henceforth CMD) to refer to language used in all CMC modes. CMD is empirically viewed as an interdisciplinary approach in the area of CMC that takes at its core the analysis of the language used in electronic environments by means of discourse analysis methods [27]. It received different labels such as 'netspeak' [3] and 'SMS speak' [28].

Such discourse is viewed as a fusion of speech and writing constituting a language variety or a register of its own [29, 30]. Unlike spoken language, CMD lacks simultaneous feedback, and non-segmental phonology is absent. Also, multiple interactions can be carried on simultaneously. Unlike written language, CMD is characterized by its dynamicity and hypertextuality [31]. Still, CMD is perceived as a new medium rather that a new variety of English [3]. As argued in [29], among the situational features that explain the linguistic manifestations of CMD are (a) the degree of participants' common background knowledge and interests, (b) the purpose of communication, (c) the roles played by an addressor, and addressee and an audience in a communicative situation, and (d) the speaker-text relationship.

The introduction of internet-based technologies caused the evolution of new linguistic practices that are the focus of the so-called "computer-mediated discourse analysis" (CMDA for short). Any analysis of online behavior that is grounded in empirical, textual observations is counted as computer-mediated discourse analysis [8]. CMDA can be employed to investigate micro-level linguistic phenomena such word formation processes, lexical choice, sentence structure, and code switching. It also studies macro-level linguistic phenomena such as coherence, cohesion, gender equity, ideology and identity as expressed through discourse [8]. CMDA assumes that (a) discourse displays concurrent language patterns produced either consciously or unconsciously, (b) discourse involves speaker's choices that help to gain insights into linguistic as well as non-linguistic phenomena, (c) CMD is subject to the technological affordances imposed by different CMC modes [8]. To recap, CMDA is an approach that relies on diverse theories and methods to explore the discourse properties displayed in different CMC modes.

IV. Methodology

A. Data

One common problem with building a corpus of text messages is that texters are always reluctant to share their messages for academic research. Therefore, it is highly recommended to collect data from different sources [32]. Therefore, data in the present study are collected from two main sources. The first source is part of Tagg's corpus of text messages [7]. I got a permission from her to use the corpus for academic research purposes, publishing substantial amounts of the corpus. The second source is different websites publishing samples of text messages. The final corpus consisted of around 15.000 words standing for 12.000 text messages created mainly by British speakers. The largest part of data has been collected between 2004 and 2007 from adult volunteers who shared their personal – rather than business – text messages. All personal information such as names, addresses, etc. are removed for the sake of texters' privacy, and they are replaced with the capital form [PRIVATE].

B. Procedure of Analysis

As mentioned earlier, the research method adopted in the present study is basically qualitative. Since the language of text messages is principally intended to mimic spoken language, the present study adapts Carter and McCarthy's model of spoken grammar [33] and Biber's Multi-Dimensional, Multi-Feature Model [34] which are markedly based on data-driven approaches. That is, the present study seeks to identify the linguistic features marking the discourse of text messages on the phonological, lexical and grammatical levels as well as to explore the communicative functions performed via these features. To achieve this objective, a three-fold procedure of analysis is followed. First, the corpus is closely investigated and the dominant linguistics features are identified and sorted through investigating the concordance lines generated by AntConc corpus analysis toolkit (3.5.8) [35]. The list of key words displayed by AntConc act as guidelines toward the investigation of the peculiar discourse shaped and reshaped by texters. These concordance lines help with identifying the frequency of the different linguistic features as they are shown across the body of the corpus (cf. Fig. 1). Second, representative, contextually-relevant examples are given and described. The representativeness of the illustrated examples is based on the rough frequency of each linguistic feature. Finally, the communicative function performed by each linguistic feature is explained in relation to other features. For this reason three key, mostly-cited references in grammar and lexis [33, 36, 37] are consulted and co-referenced.


Concordance Hits 52

Hit	KWIC
1	U NEVA CAME! C YA GAILxx Thanx 4 2day! U r a goodmate I THINK UR RITE SARY! ASUSUAL!1 U
2	. U ave a good nite? Ok :(Sounds excellent! Both r a little blocked! Call whenever you want... Hey,
3	25 YEAR OLD. SPIN OUT! GIV U DA GOSSIP L8R. AH POOR BABY! HOPE UR FEELING BETTER SN LUV!
4	u? Sez, hows u & de arab boy? Hope u r all good give my love 2 evry1 love ya esh
5	do something tomo eve. Can't remember if u r around but have contacted NAME. C u? X If

Fig. 1. Sample Concordance Lines for 'r'.

V. Data Analysis

This section analyzes the data of text messages on the phonological, lexical and grammatical levels. These three levels would give an integrative outline of the linguistic features marking the discourse of text messages from a microlinguistic perspective.

A. Phonological Features

Texters tend to find correspondences between phonemes and graphemes in order to show how language sounds. Though texting is totally performed in writing, the following features are identified.

1) Phonetic spelling: In Standard English, phonemes do not always correspond to graphemes. However, data shows many one-to-one correspondences between phonemes and graphemes. Such phenomenon is referred to as 'phonetic spelling'. Phonetic spelling fits the informal nature of CMC modes, reduces the time used for standard spelling, and conveys other auditory information. Letters and numerical digits substitute sounds within a word based on homophony, e.g. '2morrow' (tomorrow) and 'm8' (mate). Furthermore, a single letter or number can be used to replace an entire word, e.g. 'b' (be), 'r' (are) and 'u' (you). Similarly, certain letters and sounds are replaced by others. For instance, <v> replaces <th> as in '2gever' (together); <d> replaces <th> as in 'dis' (this); <i> replaces <igh> as in 'rite' (right); <f> replaces <th> as in 'fink' (think); <f> replaces <ph> as in 'fone' (phone); and <f> replaces <gh> as in 'enough'. While phonetic spellings are used creatively to speed up the course of interaction and save space, sound replacements are meant to reflect some local informal pronunciations (e.g. Th-fronting) as a way of showing identity.

2) Consonantal writing: Consonantal writing refers to the omission of vowels from words, thereby forming consonant clusters or telegraphic messages. Texters tend to delete vowels in order to save space, i.e. the 160-charater limit in each message, e.g. 'thx' (thanks), 'ppl' (people), 'tmrw' (tomorrow), 'bbq' (barbeque), etc.

3) Stress and intonation: Due to lack of verbal cues in text messages, texters tend to mark the stress and intonation of certain chunks of information through two main devices. The first strategy is the use of parenthetical brackets, e.g. Have fun and keep me texted (updated jargon), that's fine (but let me know if it changes and u can't). The second strategy is the use of capital (reduplicated) letters. Capital letters are used to draw attention to the importance of the content of the message, e.g. HOPE URE OK? TAKE CARE & I'LL SPEAK 2U SOON LOTS OF LOVE; PPL FROM WRK WILL B THERE. LOVE PETE.

B. Lexical Features

The lexical features of the discourse of text messages are explored with reference to lexical density, lexical classes, shorthand techniques, and emoticons.

1) Lexical density: The lexical density of a text can be identified through type/token ratio, mean word length and mean sentence length. It is maintained that type/token ratio is a measure of the lexical richness of a text [38]. The type/token ratio of the corpus is 21.38% which is quite high. This suggests careful word choice and more precise presentation of informational content [34, 39]. Furthermore, it is stated that the average word length in English is 5 characters [37]. Based on Microsoft Word readability statistics, the mean word length in the corpus is 3.7 characters, i.e. it is relatively short. This is justified by the use of many abbreviations, acronyms and shorthand techniques. With regard to the mean sentence length, is calculated by dividing the total number of words by the total number of sentences. The corpus shows that the mean sentence length is 8.41 characters. This is justified by the use of simple syntactic structures and modifiers. Also, the word limit for each text message force texters to use very short sentences.

2) Lexical classes: The most common lexical classes in the corpus are conjuncts, downtoners, hedges, amplifiers, emphatics and discourse markers. First, conjuncts are adverbs that add information to a sentence. They mark logical relations between clauses, relating sentence to other parts of discourse, e.g. 'never' (also spelt neva), 'rather', 'however', 'otherwise' and 'instead'. Second, downtoners (e.g. 'nearly', 'slightly', 'pretty', 'almost', etc.) are degree adverbs that indicate a degree of probability or uncertainty regarding the provided information in order to scale down the effect of the modified item [36, 37]. Also, downtoners facilitate cooperation among the communicators while forming a face-saving act on the part of the hearer [40], e.g. 'we are in one i like to share only if you knew what i meant nice', 'R u coming pub We would look slightly right of centre to u'). Third, hedges, a subclass of adverbs, are mitigating devices which mark propositions as probable or uncertain. They distinguish facts from personal opinions. Also, they are not used to make attitudinal stance. The most frequent hedges in the corpus are about, I think, sort of, and approximately as in 'well i didt come ere for ages n i wuz chief about 2 weeks ago', 'i jus nearly had a heart attack racist rap', and 'Ill call u 2mrw at ninish'.

Fourth, amplifiers are degree adverbs which boost the force of verbs, increasing their intensity. They denote emphasis, certainty and reliability of propositions. They can communicate both interpersonal and ideational information. The most common amplifiers in the corpus are 'so', 'too' (also spelt '2'), 'really', 'more', and 'very' as in 'Got to go hospital soon, really nervous, wish me luck', 'I luv u soo much u don't understand how special u r 2 me ring u 2morrow luv u'. Fifth, emphatics mark the presence of certainty and convey emotional and personal view towards the underlined proposition. Emphatics mark involvement with the topic [34]. The most frequent emphatics are 'just', 'really', 'surely', 'exactly' and 'indeed' as in 'no idea really, pickle toes and Oops just got your text'. Finally, discourse markers are syntactically-independent lexemes attached to the clause. They are claimed to facilitate ongoing interaction, mark topic shifts, indicate the speaker's attitude, make discourse more coherent, and structure the relationship among participants in a conversation [33, 37]. The most frequent discourse markers in the corpus are 'okay', 'then', 'well', 'now' and 'yeah' as in 'Ok I can go Friday', 'Mm i'm in london now and both of me are having our first drink', 'Yeah ok, i'm just watching desperate housewives'.

3) Shorthand techniques: Shorthand techniques refer to the ways in which words, phrases and sentences are shortened. The corpus shows four basic shorthand techniques: abbreviations, clips, compounds and contractions. All of these techniques are intended to speed up interaction and save space. First, abbreviations are found to stand for individual words as a letter might be homophonous to a whole word (e.g. 'c' for 'see' and 'y' for 'why'). Also, texters tend to omit vowels as in 'gs' for 'guess' and 'lrg' for 'large' and syllables as in 'fav' for 'favourite' and 'prob' for 'probably'. Similarly, apostrophe is mostly omitted as in 'cant', 'aint' and 'hes', and double letters are reduced as in 'gota' for 'gotta' and 'til' for 'till'. Some abbreviations are meant to stand for compound words as in 'NY' for 'New York' and 'neway' for 'anyway', phrases as in 'aka' for 'also known as' and 'rsvp' for 'repondez s'il vous plait', and whole sentences 'ta' for 'thanks a lot' and 'ams' for 'ask me something'.

Second, clipping refers to dropping letters from any part of a word. The most interesting examples in the corpus are 'cos' for 'because', 'THO' for 'though' and 'v' for 'have'. These clips imitate natural speech, thereby creating real environment for interaction, especially those that imitate non-rhotic /r/ as in 'neva' and 'betta' and G-clipping as in 'sumthin' and 'darlin'. Third, compounds in the corpus are not traditional as texters tend to remove spaces among words and contract them to save more space. The result is structures such as 'whaddya' for 'what do you do', 'chockablock' for 'chock-a-block', and 'WATERSHD' for 'water shed'. Still, they are not frequent as texters usually type at slower rate. Finally, contractions refer to dropping letters, usually vowels, from the middle of words. They may be standard or colloquial. Standard contractions such as 'doesn't' and 'he's' are not common. Colloquial contractions communicate emotions of affection and therefore they establish tone [41]. Based on Weber [42], contractions in the corpus include (a) progressive verbs as in 'clickin' for 'clicking' and 'gunna' for 'going to', (b) auxiliary verbs as in 's' for 'does' and 'r' for 'are', (c) modals as in 'wud' for 'would', (d) catenative verbs as in 'gotta' for 'got to', and (e) personal pronouns as in 'em' for 'them' and 'u' for 'you'.

4) Emoticons: Emoticons (or emotional icons) are textual expressions or graphical images formed from ordinary typographical symbols or ASCII characters. They are used to represent facial expressions, tone, intonation, voice inflection or feelings in CMC**.** They are surrogates of verbal, non-verbal, paraverbal cues in CMD. Metz [43] mentions four forms of emoticons: (a) verbalizing physical cues (e.g. 'hehe' for laughing), (b) using asterisks to describe physical actions (e.g. '*Lady Marion arrives in the room with a flair and arrogance fitting of her status*'), (c) stressing an utterance using capital letters (e.g. 'HEY EVERYBODY'), and (d) smileys what are characters used to communicate a feeling, and they may be graphic, symbolic (e.g. **:-)** for 'smile'), or written between two angle brackets (e.g. <s>).

In the corpus, emoticons are rarely used to verbalize physical action such as laughing as in 'hehehe'. However, asterisks are never used. Furthermore, most of the emoticons used in the corpus are symbolic. The most frequent smileys are :) 'happy', ;-) 'wink', :('sad', B-) 'cool' and =/ 'confused'. Capital letters are used to attract the attention of the addressee and they are generally used to mark physical actions especially laughter (e.g. 'LOL' and 'HAHA'), astonishment (e.g. 'WHO?'), excitement (e.g. 'EXCITING') and sadness (e.g. 'DAMMMN').

C. Grammatical Features

This section focuses on the most crucial grammatical features marking the corpus under investigation as well as their communicative functions based on the context in which they are used.

1) Tense and aspect markers: A close reading into the corpus shows that texters mostly focus on present actions and therefore most of the verbs are used in the present tense to report events (e.g. 'he writes the mail now'), plan future events (e.g. 'the group is meeting nxt week'), and comment on actions in progress (e.g. 'the game is gettin tough'). The past participle form is rarely used to state the completion of an even (e.g. 'he has bought the dragon'). The various time and aspect markers in the corpus show lexical diversity and mark informational discourse. Furthermore, most of the structures are used with first and second pronouns which indicate involvement in the discourse.

2) Adverbials: Adverbials carry much of the informational load of an utterance, indicating the place, time, manner and frequency of an action. They are markers of involvement in discourse [39]. Place adverbials indicate distance, direction, or position as in 'what's new around here?' and 'ur m8s agen after u bein racist towards dem'. Based on the common classification of the functions of time adverbials [37], the time adverbials in the corpus are used to tell time (e.g. 'now', 'early', 'later', etc.), express duration (e.g. 'for'), convey frequency (e.g. 'again', 'once', etc.), and mark temporal relationships (e.g. 'before', 'after', 'while', etc.). With regard to manner adverbials, they are used to reflect on how different actions are performed. The corpus shows that they are basically used to modify verbs rather than adjectives and other adverbs (e.g. 'I was perfectly nice to you', 'things which are literally and physically not possible'). Finally, frequency adverbials are used to describe how often an action happens. The corpus show that they are often used after verb to be (e.g. 'im always bumpin in 2 ppl i kno'), before verbs (e.g. 'they only have 1 grandchild down here') and before nouns and adjectives (e.g. I surrender to every word u whisper).

3) Nominal forms: Nominal forms refer to the way nouns are formed, and they are related to information packing in an utterance. The corpus shows that nouns in the discourse of text messages are formed through nominalization, gerunds and nouns. Most of nominal forms are formed with suffixes, e.g. -er, -tion, -ence, and -ness. Nominalizations tend to pack much information in few words while expanding textual units [39]. Similarly, nominalization renders discourse more objective, summarizes propositional content, and contributes to the informational load of a text [44]. Like nominalizations, gerunds and present participle forms integrate information as in 'Hey j! r u feeling any better, hope So hunny', 'did you have any luck catching PRIVATE?' and 'PRIVATE has just rung me wanting your number'. Indeed, nouns are the most frequent grammatical category in the corpus as they function as referential specifiers referring to places, times, tools, abstract ideas, professions and people.

4) Adjectives: Adjectives expand information and limit its scope. The corpus shows three categories of adjectives: inflectional (e.g. 'All the best this afternoon'), periphrastic (e.g. 'Try that hotel. It is more convenient') and basic (attributive and predicative). Basic adjectives are the most frequent as attributive adjectives are descriptive (e.g. 'I have just come over all hot, sweaty, shaky and feel faint!') while predicative adjectives are emotive (e.g. 'anything that is warm').

5) Pronouns: Pronouns are used when the entities referred to are situationally prominent and when the reference is general [37]. Though they economize speech, they offer accurate specification. The corpus shows the use of personal, demonstrative, and indefinite pronouns. Personal pronouns mark a great deal of involvement among chatters. Accordingly, the absences of personal pronouns indicate impersonality. They are classified into first person, second person and third person pronouns. First and second person pronouns are used excessively to show involvement in discourse, while third person pronouns show involvement with the topic rather than the addressee. It is noteworthy that the pronoun 'it' is rarely used since the discourse of text messages is not continuous. One more device that supports cohesion in the discourse of text messages is the use of demonstrative pronouns (e.g. 'this', 'that', 'these' and 'those') with some dialectical variations (e.g. 'dat' and 'dis'). Most of the demonstrative pronouns are used with nominal referent, thereby participating in clarifying their referents as in 'PRIVATE, is this your phone still?'. Finally, indefinite pronouns (e.g. 'all', 'much', 'everthin', 'every1', 'nething', etc.) are sometimes used in case a texter does not want to make himself/herself explicit as in 'hope all is well', and 'Another successful night, was a big hit'.

6) Questions: Questions generally shows interest and involvement in discourse. One key function of text messages is to ask for information on a variety of topics. Wh-questions mark a high degree of interpersonal interaction and personal involvement [34]. Texters in the corpus under investigation use different forms of questions as in 'Y did you volunteer?' and 'WHO IS THIS SI THEN?' Unlike Wh-questions, yes-no questions request a truth value based on elements already mentioned in the questions. Yes-no questions open with the operator (an auxiliary or a modal) followed by the subject. By answering 'yes' or 'no', the addressee supplies a truth value by opting for one of the already specified elements. However, the addressee may also supply additional information. The following statistics represent the frequency of yes-no questions in both corpora. In the discourse of text messages, they speed up the course of interaction as they offer quick short answers as in 'do you still have a spare big chill?' and 'can you please give PRIVATE and family my condolences tomorrow?'. The last form of questions is alternative question (also known as 'OR questions'). Like yes-no questions, they provide quick short answers by opting for one alternative as in 'shall we meet at 9 or 10 2mrw?'

7) Passives: Passive structures foregrounds the content rather than the agent. However, the agent may be deleted (i.e., agentless passives) or confirmed (i.e., by-passives). Agentless passive syntactic structures render the information offered in a text message as static and abstract. The corpus displays two basic passive structures: be-passive (be + past participle) and get-passives (get + past participle). Be-passive structures simply describe a state as in 'these tools were invented by PRIVATE' and 'their visas have been denied and they cant reenter'). Whereas get-passive describe the process of getting into a new state as in 'PRIVATE get drunk n make friends'.

8) Modals and semi-modals: Modals are indicative of language users' attitudes toward topics. They are generally classified into pure modals and semi-modals. Pure modals keep the same form and aspect, and they are negated with 'not'. Also, they are followed by the base form of the verb. Based on the semantic notion impeded within pure modals, the corpus displays five categories of modals: (a) obligation and necessity modals (e.g. 'must', 'shouldn't', 'shud', etc.) as in 'I should get my card tonight', (b) ability and possibility modals (e.g. 'can', 'cud', 'couldn't', etc.) as in 'IF WE MEET WE CAN GO 2 MY HOUSE', (c) epistemic possibility modals (e.g. 'mite', 'may', etc.) as in 'PRIVATE may be l8 if he goes at 7', (d) volition and prediction modals (e.g. 'will' and 'shall') as in 'U WILL SWITCH YOUR FONE ON DAMMIT', and (e) hypothetical modals (e.g. 'wud', 'would' and 'wouldn't') as in 'we would drop in 2nt'. In general, these modals are used to offer more details about the meaning of the main verb and to communicate certain attitudes and social relations. Unlike modals, semi-modals are multi-word constructions that function like modals, e.g. 'ought to', 'be going to', 'need to' and 'be able to'. Their form and aspect change. They are basically intended to show informal style, particularly when contracted forms such as 'gonna' are used as in 'PRIVATE is going to ask big PRIVATE if i can go on 3 month trial'.

VI. Results

Based on the results of the studies previously reviewed herein, it becomes clear that computer-mediated discourse has emerged as a result of adaptation to the technological constraints posed by different technological affordances. Such technological affordances arise from the material characteristics framed through the properties of the electronic environment offered by various CMC modes as well as users' cultural and individual knowledge that is employed to perform interpersonal functions. Furthermore, these affordances are spatio-temporal in the first place. As an asynchronous CMC mode, text messages are produced at a slow rate and hence they carry much of the properties of planned speech. Space also is another crucial affordance as texters have to abide by 160 characters only per message, thereby rendering the discourse of text messages markedly economic. That is, reductions in general save time and space and speed up the communication process which pertaining to the common properties of both spoken and written languages. Though it is interactive and revisable, the discourse of text messages is not time-bound. Rather, it is space-bound and visually decontextualized. In short, all of these factors and constraints underlie the peculiar linguistic properties of text messages discourse on the phonological, lexical and grammatical levels. The corpus tool, represented by AntConc corpus analysis toolkit (3.5.8) [35], helped to compare and sort such features.

On the phonological level, although the discourse of text messages is basically communicated in a written form, it is found it contains various phonological surrogates that compensate segmental and suprasegmental phonological features. The most common phonological features are phonetic substitution, sound replacement, capital letters and letter-number homophones. Texters substitute letters in irregular standard spelling for those corresponding to particular sounds and even syllables, e.g. '2' for 'two', 'to', 'too' and and '2gether'. Consonants are sometimes replaced by others, especially 'th' that is replaced by 'f' as in 'fink', or 'd' as in 'da' or 'v' as in 'wiv'. Also, the deletion of many vowels in text messages render most of them as telegraphic. Capital letters are used to mark intonation and stress shift as in 'I will do it 2DAY'. Finally, letter-number homophones are used to save space and speed up communication.

Obviously, the corpus is lexically rich. Still, the type/token ratio of the corpus proved to be not high. Similarly, the average word length is below the average word length in Standard English. These features are typical of informal writing and interactive discourse. The most frequent lexical classes in the corpus are conjuncts, downtoners, hedges, and discourse markers. All of these classes are used to communicate various attitudes such as (un)certainty, seriousness, authenticity and involvement. For spatio-temporal reasons, shorthand techniques abound in the discourse of text messages. Abbreviations are created by apostrophe omission, clipping, double letter reduction, letter(s) omission, and syllable omission. They are found to stand for individual words, compound words, phrases and whole sentences. Equally important, emoticons are employed to offer non-textual information and to regulate interaction.

Similarly, texters tend to use peculiar grammatical features that best communicate their attitudes, stances and intentions. Almost all tense and aspect markers, including the base form, the present and past participles as well as the infinitive, present and past forms, are used in the corpus. This shows highly packed information despite the short texture of text messages. Such information cover the time, place, manner, and frequency of events, and they are highlighted via frequent adverbials. Also, different nominal and adjectival forms are used to expand and elaborate on the propositional content of messages. In addition, pronouns are used to mark personal relationships, show involvement in the discourse, and render the discourse of text messages referentially cohesive. Similarly, questions, particularly wh-questions, are employed to maintain interaction and trigger additional information. Finally, modals and semi-modals are used in the first place to encode texters' attitudes and to attach an evaluative tone to the message.

VII. Conclusion

The present study went beyond the superficial description of the linguistic features of the discourse of text messages. It took as it core the communicative functions performed by each linguistic feature taking into consideration the linguistic context of the whole utterance. The study hopefully contributes to our knowledge about the way technological devices motivate specific language behavior. The findings would help with enhancing mobile learning strategies and applications by offering content peppered with the linguistic features that texters usually use in their casual communications. Further future research is recommended to apply both quantitative and qualitative methods to explore the frequency of different linguistic features particular to the discourse of text messages and to identify the pragmatic as well as the cognitive basis for paradigmatic variations in such discourse. Also, further research would investigate the role played by gender in the formulation of the discourse of text messages.

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Flood Damage Area Detection Method by Means of Coherency Derived from Interferometric SAR Analysis with Sentinel-A SAR

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***Abstract*—Flood damage area detection method by means of coherency derived from interferometric SAR analysis with Sentinel-A SAR is proposed. One of the key issues for flooding area detection is to estimate it as soon as possible. The flooding area due to heavy rain, typhoon, severe storm, however, is usually covered with clouds. Therefore, it is not easy to detect with optical imagers onboard remote sensing satellite. On the other hand, Synthetic Aperture Radar: SAR onboard remote sensing satellites allows to observe the flooding area even if it is cloudy and rainy weather conditions. Usually, flooding area shows relatively small back scattering cross section due to the fact that return signal from the water surface is quite small because of dielectric loss. It, however, is not clear enough of the flooding area detected by using return signal of SAR data from the water surface. The proposed method uses coherency derived from interferometric SAR analysis. Through experiment, it is found that the proposed method is useful to detect the flooding area clearly.**

Keywords*—*Flooding area detection; Synthetic Aperture Radar: SAR; interferometric SAR analysis; coherency; back scattering cross section; remote sensing satellite

I. Introduction

One of the key issues for flooding area detection is to estimate it as soon as possible. The flooding area due to heavy rain, typhoon, severe storm, however, is usually covered with clouds. Therefore, it is not easy to detect with optical imagers onboard remote sensing satellite. On the other hand, Synthetic Aperture Radar: SAR onboard remote sensing satellites allows to observe the flooding area even if it is cloudy and rainy weather conditions.

Flooding and oil spill disaster relief using Sentinel of remote sensing satellite data is conducted [1]. SAR image classification based on Maximum Likelihood Decision rule with texture features taking into account a fitness to the probability density function is proposed [2]. On the other hand, a new method for SAR speckle noise reduction (Chi-Square Test Filter) is proposed and validated with actual satellite based SAR data [3].

Decomposition of SAR polarization signatures by means of eigen-space representation is proposed [4]. Meanwhile, polarimetric SAR image classification with maximum curvature of the trajectory in eigen space domain on the polarization signature is attempted [5]. On the other hand, Wavelet Multi-Resolution Analysis: MRA and its application to polarimetric SAR classification is proposed and validated [6].

Sentinel 1A SAR data analysis for disaster mitigation in Kyushu, Japan is conducted [7]. On the other hand, polarimetric SAR image classification with maximum curvature of the trajectory in eigen space domain on the polarization signature is proposed [8].

Polarimetric SAR image classification with high frequency component derived from wavelet multi resolution analysis: MRA is proposed and validated [9]. Also, comparative study of polarimetric SAR classification methods including proposed method with maximum curvature of trajectory of backscattering cross section in ellipticity and orientation angle space is conducted [10].

Characteristics of heavy rainfall and flood disaster in central southern part of Oita prefecture by Typhoon No.18 "Typhoon Talim" in 2017), flooding areas in the Tsukumi city due to Typhoon No.18 are investigated [11]. Sentinel 1A SAR data analysis for disaster mitigation in Kyushu is conducted and reported [12], Also, Wavelet Multi-Resolution Analysis: MRA and its application to polarimetric SAR classification is proposed [13].

Usually, flooding area shows relatively small back scattering cross section due to the fact that return signal from the water surface is quite small because of dielectric loss. It, however, is not clear enough of the flooding area detected by using return signal of SAR data from the water surface. The proposed method uses coherency [1] derived from interferometric SAR analysis. Through experiment, it is found that the proposed method is useful to detect the flooding area clearly.

The following section describes research background, in particular, flooding damage due to typhoon No.18, which hit Japanese island. Then some experimental results, in particular, a comparison of flooding area observed on the ground and detected flooding area using Sentinel-1 SAR data through interferometric SAR analysis (coherency). After that conclusion is described with some discussions.

[1] https://en.wikipedia.org/wiki/Coherence_(signal_processing)

II. Research Background

A. Typhoon No. 18 in 2017

Typhoon No. 18, which occurred in the Mariana Islands on September 9 in 2017, traveled northwest in the south of Japan, and moved northward near Miyakojima on the 13th with a very strong force. The typhoon turned to the east in the East China Sea on the 15th in September and landed near Minamikyushu City in Kagoshima Prefecture at around 11:30 on the 17th in September. After that, the typhoon moved north along the Japanese archipelago along with the storm area, re-landed in Kochi prefecture, Hyogo prefecture, and Hokkaido, and became a temperate cyclone in Sakhalin at 21:00 on the 18th in September.

Due to the effects of typhoons and active fronts, heavy rains and storms occurred mainly in the Nansei Islands, western Japan, and Hokkaido. In addition, due to the typhoon, the storm surged mainly in the Nansei Islands and western Japan, and the storm surge occurred mainly in western Japan because it coincided with the tide.

Due to these effects, river floods, flood damage, and sediment disasters occurred mainly in Oita prefecture and western Japan. In addition, there were damages to lifelines such as water outages and telephone interruptions in various places, as well as traffic disruptions such as suspension of railroads and cancellation of aircraft and ships. Fig. 1 shows the trajectory of the typhoon No.18, Talim which hit Japanese island during on 17th of September and 18th of September 2017.. Also, Fig. 2 shows Geo-stational Meteorological Satellite image of Typhoon No.18 over Kyushu, Japan acquired on 17 September 2017.

B. Intensive Study Areas

Fig. 3 shows the intensive study area of Usuki and Tsukumi areas of Kyushu, in Japan of which flood damaged areas due to Typhoon No.18 during 17 and 18 September 2017.

Fig. 1. Trajectory of the Typhoon No.18.

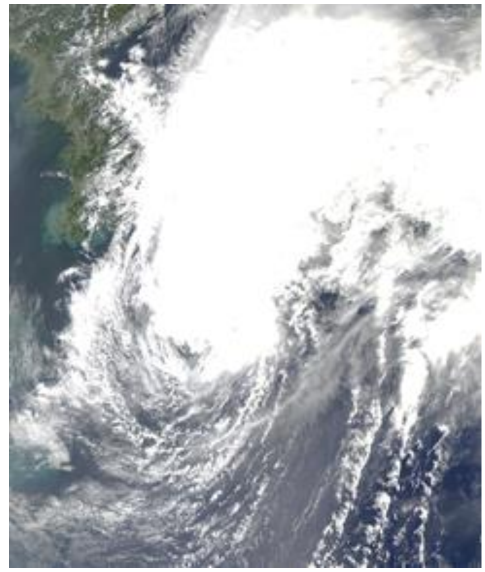


Fig. 2. Geo-Stational Meteorological Satellite image of Typhoon No.18 over Kyushu, Japan Acquired on 17 September 2017.

(a) Intensive Study Areas.

(b) Enlarged Google Map Image of the Intensive Study Areas.

Fig. 3. Intensive Study Area of Usuki and Tsukumi Areas of Kyushu, in Japan of which Flood Damaged Areas due to Typhoon No.18 during 17 and 18 September 2017.

C. Rainfall Rate and Wind Direction as well as Wind Speed

From Journal of Japanese Society on Natural Disaster Science, 36 -4 381 -397 (2018) by Haruhiko YAMAMOTO, Toshiaki YAMASAKI, Kyoko SAKAMOTO and Nao YAMASHITA, Characteristics of Heavy Rainfall and Flood Disaster in Central Southern part of Oita Prefecture by Typhoon No.18 "Typhoon Talim" in 2017 [11], rainfall rate and ground wind direction and wind speed are investigated. These are shown in Fig. 4.

Prof. Dr. Yamamoto conducted ground survey of the flooding situation in the Tsukumi city in Oita prefecture of Japan. The flooding areas in the city is shown in Fig. 5.

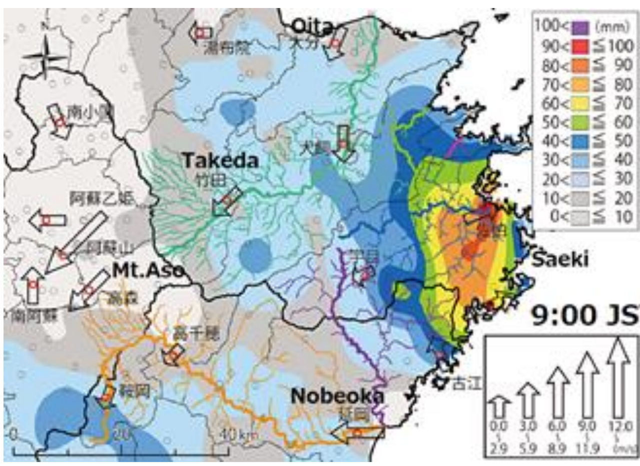
D. Damage Due to Typhoon No.18 Which Hit Kyushu on 17th of September 2017

Major damages due to Typhoon No.18 are as follows,

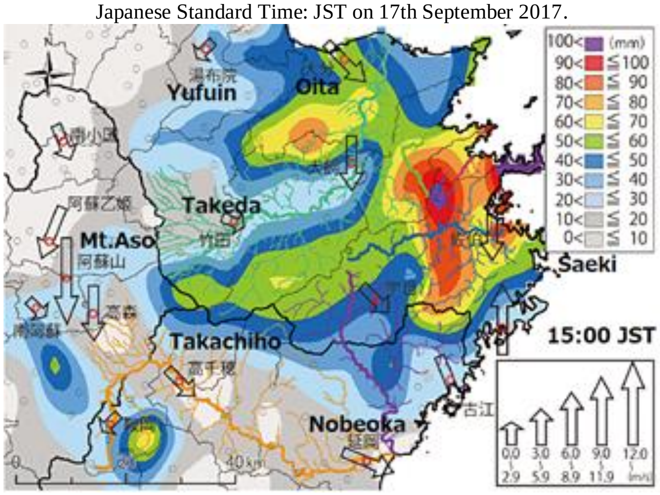
1) 5 dead, 59 injured.

2) Completely destroyed 3 houses, 11 partially destroyed, 531 partially destroyed.

3) 1,970 buildings on the floor, 4,653 buildings under the floor, etc.



(a) Wind Direction and Wind Speed as well as Rainfall Rate Observed at 9:00 Japanese Standard Time: JST on 17th September 2017.



(b) Wind Direction and Wind Speed as well as Rainfall Rate Observed at 15:00 Japanese Standard Time: JST on 17th September 2017.

Fig. 4. Wind Direction and Wind Speed as well as Rainfall Rate Observed at 9:00 and 15:00 Japanese Standard Time: JST on 17th September 2017.

Fig. 5. Flooding Areas in the Tsukumi City Due to Typhoon No.18 (From Journal of Japanese Society on Natural Disaster Science, 36 -4 381 -397 (2018) by Haruhiko YAMAMOTO, Toshiaki YAMASAKI, Kyoko SAKAMOTO and Nao YAMASHITA, Characteristics of Heavy Rainfall and Flood Disaster in Central Southern part of Oita Prefecture by Typhoon No.18 "Typhoon Talim" in 2017).

In Oita prefecture, many rivers from central Oita prefecture to southern Oita prefecture flooded on the 17th. In Usuki City, the city was flooded, and the Governor of Oita issued a disaster dispatch request to the 41st Ordinary General of the Ground Self-Defense Forces in charge of flood control (disaster dispatch request was made at 13:00 on the 18th of the following day). In Tsukumi City, the Tsukumi River and Tokuura River flooded and flooded a wide area, including the Tsukumi City Hall. In addition, floods also occurred in the Ono River in Oita City and Bungo Ono City, the Isaki River in the Bansaku River System in Saiki City, and also in the Fengaru River in Usuki City and the Monzen River in Saiki City.

In Oita prefecture, river water is flooding everywhere. In Tsukumi City, the river flowing through the city overflowed and a wide area was flooded. After 3:00 pm on September 17, water flowed into the 1st floor of the city hall, temporarily using the height of the ankle, and most of the surrounding area was flooded with water, and some cars floated on the water in the parking lot. In Bungo-Ono City, around 4 pm on September 17, part of the Ono River in the shallows of Mie Town overflowed with water, and three houses along the river were flooded under the floor. Also, in Beppu City, Oita Prefecture, around 4 pm on the 17th September, earth and sand collapsed on the back mountain of the house. The back mountain collapsed over a height of about 5 meters and a width of about 5 meters, and the window glass on the first floor of the house was broken, but there were no injuries. At the Nishinomiya Shrine in Takeda City, Oita Prefecture, it was discovered that a stone wall 4 meters high collapsed over a width of 4 meters.

The collapsed stone wall is said to have collapsed to the site of the next house, but there is no damage to people or buildings. "In Tsukumi City, Oita Prefecture, where it seems to have been raining about 110 mm per hour, it seems that the river flowing through the city overflowed and a large area was flooded, but police and fire departments were all over the road. He said that he could not patrol as expected after flooding, and that he did not understand the full extent of the damage.

According to Tsukumi City, the residents flooded the Tsukumi River and Tokuura River, which flowed in the city from about 2:30 pm, with messages saying that the underfloor of the house was flooded. After 3:00 pm, the water flowed to the first floor of the city hall, and the height of the ankle was used for a while.

Depending on the city, water gradually begins to drain, and as of 6:00 pm, the flood in the city hall has disappeared, and there are some roads around the city where water can begin to drain. However, according to police and fire departments, the roads are still flooded everywhere in the city, so the patrol to confirm the damage does not proceed as expected and the whole situation is not grasped.

III. Proposed Method

A. Interferometric SAR

The signals received by antennas 1 and 2 are processed to generate two sets of complex images, and the product $A_1A^*{}_2 = |A_0|^2$ of the complex amplitude A_1 of image 1 and the complex conjugate $A^*{}_2$ of image 2 called interferogram.

$$\exp(i\varphi) = |A_0|^2 (\cos(\varphi) + i \sin(\varphi)) \tag{1}$$

where, $\varphi = \varphi_1 - \varphi_2 = 2k (R_1 - R_2)$ is the phase difference, $k = 2\pi / \lambda$ is the wave number, and A_0 is a constant including RCS and is constant throughout both images. The phase of the interferogram is as follows,

$$\psi = \arctan(\text{imag.}(A_1A^*{}_2) / \text{real}(A_1A^*{}_2)) = \varphi + j2\pi: \quad j = 0, \pm 1, \pm 2, \pm 3, \ldots \tag{2}$$

Extracted phase ψ is folded between $(0, 2\pi]$ every 2π, and the absolute phase (absolute or unwrapped phase) is calculated by removing the ambiguity of 2π from the wrapped phase. This processing technique is called phase unwrapping or phase recovery, and many methods have been proposed. Relationship between phase of interferogram and ground surface height $\varphi = (4\pi / \lambda)$ BCT $\sin(\theta_i - \gamma CT)$. The ground surface altitude is obtained, but at present, it is difficult to obtain highly accurate orbit information from platform information. Therefore, the change in the ground surface height is as follows,

$$\Delta H = \lambda R_1 \sin\theta_i \, 4\pi BCT \cos(\theta_i - \gamma CT) \, \Delta\varphi \tag{3}$$

And is extracted from the difference between the two points on the image. Here, ΔH and $\Delta\varphi$ are the change in the ground surface altitude and the change in the interferogram phase at two points, respectively. In actual processing, there is speckle-specific noise in the coherent imaging system, so arithmetic processing is performed as a set average interferogram phase with some noise reduction. The coherence image showing the correlation of complex images is defined by the following equation:

$$\Gamma_{12} = |A_1A^*{}_2| / I_1 I_2 \tag{4}$$

where, I_j; (j = 1, 2) represents the set average of the intensities I_j.

The coherence of the interferogram generated by the interferometric SAR and the differential interferometric SAR described later depends on the degree of correlation of the backscatter field. In the repeat path InSAR, when the scatterer changes between paths, the degree of correlation of the backscattering field decreases and the coherence of the interferogram also decreases. In forests where the volume scattering is the main, the coherence may decrease due to the change of the reflection path due to a slight difference in the incident angle. Utilizing this phenomenon, research is being conducted to measure the characteristics of spatterers and spatiotemporal changes from coherence. For example, if λ = 23.5 cm, R_1 = 750 km, $\gamma CT = 0$, θ_i = 40 °, and BCT = 1 km, one cycle of interference fringes corresponds to an altitude difference of about 74 m. The longer the orbital interval, the shorter the interval of interference fringes and the higher the measurement accuracy. In order to generate a good quality interferogram, there is a trade-off between the two.

For satellite C-band SAR such as ENVISAT-ASAR and RADARSAT-1, the available orbital intervals are around 0.5km and the JERS-1 L-band SAR., it is about 1 km. Regarding the accuracy of the InSAR-DEM, the DEM by airborne In-SAR has an error of about 2 to 5 m compared with the DEM obtained from optical stereo vision, but the error by using multi-wavelength and multi-polarization InSAR It has been reported that the result can be reduced by about 30%. As the slope of the ground surface increases, layover, foreshortening, and shadow effects increase and coherence decreases, so the measurement error generally increases.

It is difficult for satellite-borne InSAR to completely eliminate interference fringes due to orbital intervals due to the uncertainty of orbit information and the curved surface of the ground surface. This is due to coherence degradation due to ground surface inclination and signal delay due to atmospheric water vapor Due to some errors, the measurement error from a single interferogram is often several meters to several tens of meters. However, satellite orbit information is becoming more accurate, and it is possible to reduce the measurement accuracy below the resolution range by using multiple interferograms with high coherence generated from data under different orbit intervals and meteorological conditions.

B. Proposed Method

The definition of the coherence for complex data is given by the following equation,

$$\mu_0 = <(x_1 - <x_1>)((x_2 - <x_2>)^* > (\sigma_{x_1}\sigma_{x_2}) \tag{5}$$

where: < > is the expectation operator x_1, x_2 are the pixels from the two images being correlated, image 1 and 2, respectively. * denotes complex conjugate while σ_{xi} is the square-root of the variance for the pixel from the i-th image.

The proposed method for flooding area detection is to use the coherency. Namely, coherency reflects correlation between two SAR imagery data, master and slave images. Therefore, correlation between two SAR imagery data, before and after the typhoon hit the intensive study areas supposed to be flooding areas.

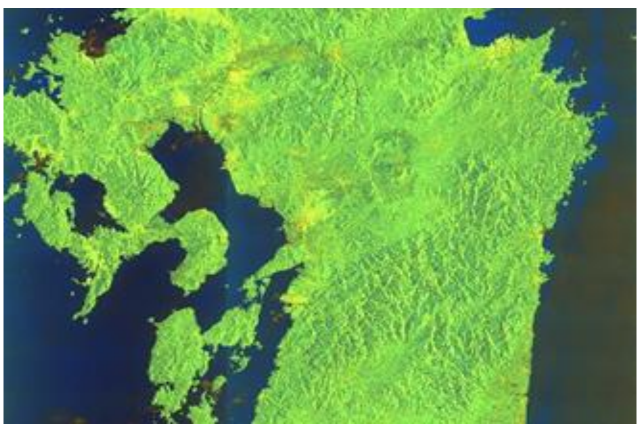
The coherency between two SAR imagery data (before flooding and after flooding) indicates the difference of back scattering cross section of the land surface covered with water. Therefore, it is possible to detect flooding areas by using coherency which is expressed with the equation (5).

IV. Experiment

A. Data used

The following Sentinel-1A SAR imagery data (see Fig. 6) which are acquired on September 7 in 2017 (just before the Typhoon No.18) and September 19 in 2017 (just after the Typhoon No.18) are used for the experiment.

Descending orbit (Descending path)
Observation wavelength: C band
Polarization: VV
Date of disaster (central day): September 16-17, 2017 (JP)
Data used for processing...
Two periods before the disaster
Time 1: August 26, 2017 (JP), preliminary orbit data
Period 2: September 7, 2017 (JP), preliminary orbit data
Two times between the days of disaster
Timing 1: September 7, 2017 (JP), preliminary orbit data
Period 2: September 19, 2017 (JP), preliminary orbit data


(a) September 7(Before Typhoon No.18).

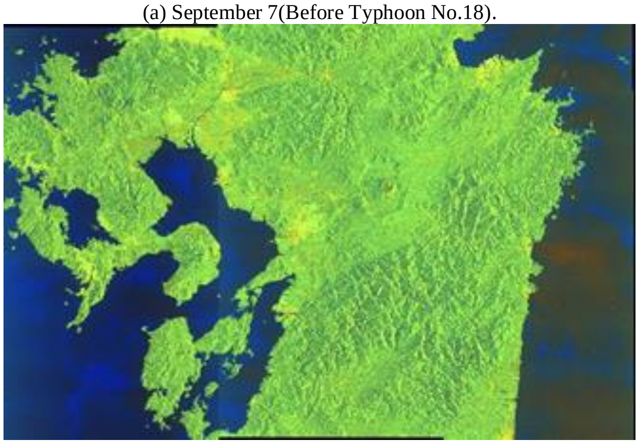

(b) September 19(After Typhoon No.18).

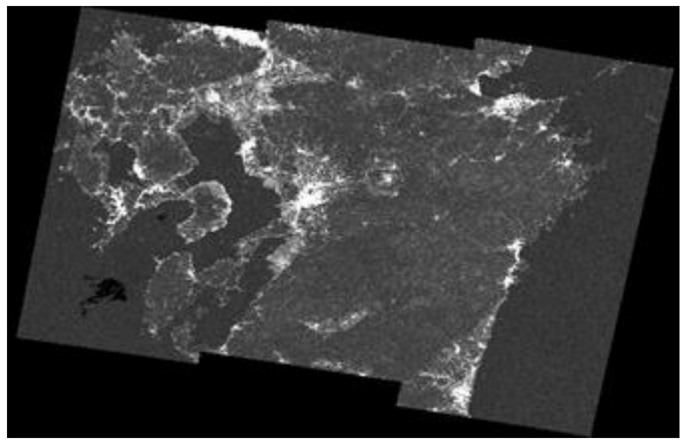
Fig. 6. Two Sentinel-1A SAR Imagery Data used.

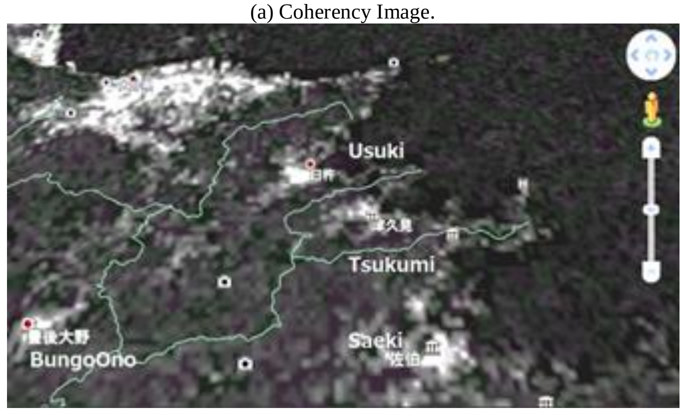
B. Coherence Image

Using the aforementioned two Sentinel-1A SAR imagery data (before and after the typhoon No. 18), coherency defined as Eq. 5 is calculated. The resultant coherency image is shown in Fig. 7(a). Meanwhile, Fig. 7(b) shows the coherence image on Google Earth while Fig. 7(c) shows coherence image of the intensive study area and Fig. 7(d) shows the intensive study area on Google map.

C. Major Result

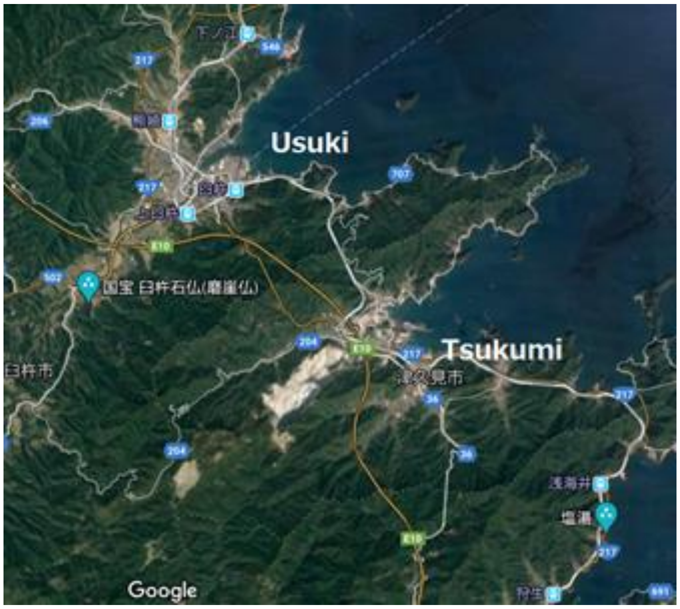
In comparison between the Fig. 7(c) (derived from the coherence image) and Fig. 5 (Truth data of flooding areas), it is confirmed coincidence between both. Namely, proposed method for flooding area detection using coherence image does works well.


(a) Coherency Image.



(b) Coherency Image on Google Earth.

(c) Enlarged Coherency Image of the Intensive Study Area.



(d) Intensive Study Area on Google Map.

Fig. 7. Coherency Image of the Intensive Study Area.

D. Elevation Changes between Two Periods, before and after the Typhoon No.18

Using interferogram derived from two Sentinel-1A SAR imagery data (before and after the typhoon No.18), it is possible to create the elevation changes during the typhoon No.18. The resultant elevation change image is shown in Fig. 8.

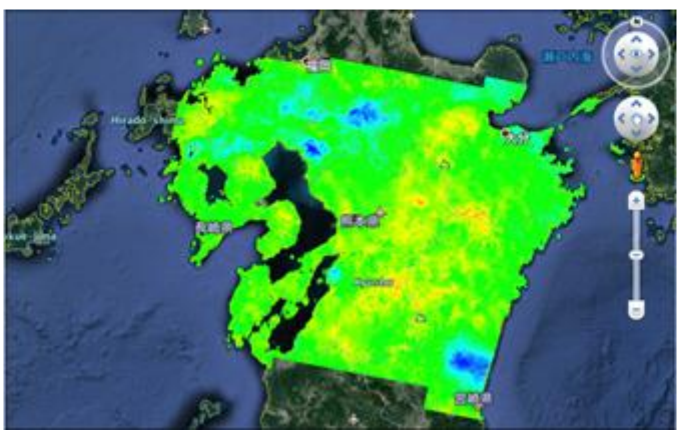


Fig. 8 Interferogram showing elevation changes between two time periods, before and after the Typhoon No.18

V. CONCLUSION

Flood damage area detection method by means of coherency derived from interferometric SAR analysis with Sentinel-A SAR is proposed. One of the key issues for flooding area detection is to estimate it as soon as possible. The flooding area due to heavy rain, typhoon, severe storm, however, is usually covered with clouds. Therefore, it is not easy to detect with optical imagers onboard remote sensing satellite. On the other hand, Synthetic Aperture Radar: SAR onboard remote sensing satellites allows to observe the flooding area even if it is cloudy and rainy weather conditions. Usually, flooding area shows relatively small back scattering cross section due to the fact that return signal from the water surface is quite small because of dielectric loss. It, however, is not clear enough of the flooding area detected by using return signal of SAR data from the water surface. The proposed method uses coherency derived from interferometric SAR analysis. Through experiment, it is found that the proposed method is useful to detect the flooding area clearly.

In comparison between the Fig. 7 (c) (derived from the coherence image) and Fig. 5 (Truth data of flooding areas), it is confirmed coincidence between both. Namely, proposed method for flooding area detection using coherence image does works well.

VI. FUTURE RESEARCH WORKS

Further research works are required for the conventional method using optical sensor data and interferogram. Also, classification methods have to be tried to detect flooding areas in remote sensing satellite imagery data.

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AUTHOR'S PROFILE

Kohei Arai, He received BS, MS and PhD degrees in 1972, 1974 and 1982, respectively. He was with The Institute for Industrial Science and Technology of the University of Tokyo from April 1974 to December 1978 also was with National Space Development Agency of Japan from January, 1979 to March, 1990. During from 1985 to 1987, he was with Canada Centre for Remote Sensing as a Post Doctoral Fellow of National Science and Engineering Research Council of Canada. He moved to Saga University as a Professor in Department of Information Science on April 1990. He was a councilor for the Aeronautics and Space related to the Technology Committee of the Ministry of Science and Technology during from 1998 to 2000. He was a councilor of Saga University for 2002 and 2003. He also was an executive councilor for the Remote Sensing Society of Japan for 2003 to 2005. He is a Science Council of Japan Special Member since 2012. He is an Adjunct Professor of University of Arizona, USA since 1998. He also is Vice Chairman of the Science Commission “A” of ICSU/COSPAR since 2008 then he is now award committee member of ICSU/COSPAR. He wrote 55 books and published 620 journal papers as well as 450 conference papers. He received 66 of awards including ICSU/COSPAR Vikram Sarabhai Medal in 2016, and Science award of Ministry of Mister of Education of Japan in 2015. He is now Editor-in-Chief of IJACSA and IJISA. http://teagis.ip.is.saga-u.ac.jp/index.html.

Barley Quality Estimation Method with UAV Mounted NIR Camera Data based on Regressive Analysis

Prediction Method of Anthocyanin, β-glucan and Water Contents in the Harvested Daishimochi of Barley Grains before the Harvest

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***Abstract*—Barley quality estimation method with Unmanned Aerial Vehicle: UAV based Near Infrared: NIR camera data based on regressive analysis is proposed. The proposed method allows to predict barley quality, anthocyanin, β-glucan and water contents in the harvested "Daishimochi" of barley grains before the harvest. The prediction method proposed here is based on regression analysis with the Near Infrared: NIR camera data mounted on UAV which allows to estimate barley quality, anthocyanin, β-glucan and water contents in the harvested "Daishimochi" of barley grains before the harvest.. This is the first original attempt for the prediction in the world. Through experiment, it is found that water content (%), Anthocyanin content (mg Cy3G/100 g), Anthocyanin content (mg Cy3G/100 g: which corresponds to dry matter), and barley β-glucan (%) can be predicted before the harvest with high R^2 value (more than 0.99). Therefore, farmers can control fertilizer and water supply for improvement of the Daishimochi barley grain quality.**

Keywords—Unmanned Aerial Vehicle: UAV; Near Infrared: NIR camera; Daishimochi; anthocyanin; β-glucan and water contents; barley quality

I. Introduction

There is a strong demand on a prediction of the harvested agricultural product quality before the harvest. If it is possible to predict, farmers may control fertilizer, water supply to get better quality of the agricultural products.

"Mochi barley" is composed only of amylopectin, and this difference creates stickiness when cooked. The reason why "mochi wheat" is receiving attention is the improvement of the intestinal environment. The key ingredient is the water-soluble dietary fiber called "barley β-glucan" that was introduced at the beginning. It has been reported that it functions as a food for good bacteria in the intestine to adjust the intestinal environment.

Furthermore, it has been reported that it suppresses the absorption of sugars and suppresses the rise in blood sugar level after eating. The function of "barley β-glucan" is not limited to that. It is also reported that it has a strong viscosity and absorbs cholesterol to help it be excreted from the body.

"Mugigohan" is the best way to efficiently take in "mochi wheat," which is full of energy for your body. Especially, it is recommended to incorporate it in "breakfast". The reason is that "barley β-glucan" suppresses the absorption of sugars and continues until the next meal. This feature is called the "second meal effect".

This barley (bare barley) was grown in 1997 at the Shikoku Agricultural Experiment Station in Zentsuji City, Kagawa Prefecture, and was named "Daishimochi" because of Kobo Daishi, who is associated with Zentsuji. Although the same mochi barley has different characteristics depending on the variety, "Sanuki Mochi barley Daishimochi" is a purple-colored grain with a sweetness and a fluffy, chewy texture. It contains about 30 times as much dietary fiber as polished rice and is rich in β-glucan (water-soluble dietary fiber).

The prediction method proposed here is based on regression analysis with the Near Infrared: NIR camera data mounted on UAV which allows to estimate barley quality, anthocyanin, β-glucan and water contents in the harvested "Daishimochi" of barley grains before the harvest. This is the first original attempt for the prediction in the world.

The following section describes research background and related research works. Then experiment is described with some remarks. After that, conclusion is described with some discussions and future works.

II. Research Background and Related Research Works

A. Research Background

The anthocyanins of the Daisimochi grain are mainly composed of cyanidin malonyl glucoside and localized in the pericarp. In recent years, physiological activities of anthocyanins such as antioxidative activity, anti-inflammatory activity and blood glucose lowering activity have been clarified, and cereals containing anthocyanin pigment have been attracting attention as a supply source thereof. The conventional glutinous barley and the cultivar "Daishimochi" which has improved cultivability have a characteristic of being colored purple during the ripening period, but the pigment is not used so much. Therefore, in order to effectively utilize the anthocyanin pigment contained in Daishimochi grain, its main component and the accumulation of the ripening process are clarified, and the localization in the grain is investigated by the polishing.

Daishimochi grains contain anthocyanins. The main component is cyanidin 3-(3″,6″-dimalonyl glucoside) containing 2 malonyl groups, then cyanidin 3-(6″-malonyl glucoside) containing 1 malonyl group and cyanidin 3-(3″) -Malonyl glucoside), and cyanidin 3-glucoside having no malonyl group.

In Daisimochi kernels, anthocyanins accumulate after 28 days after flowering, peak at 35 days after flowering, and decrease at 42 days after flowering. The most abundant cyanidin 3-(3″,6″-dimalonyl glucoside) is contained throughout the ripening period. The anthocyanin accumulation time is later than the accumulation time of catechin and proanthocyanidins, which are the causes of browning after heating and are the main polyphenol components of barley grain.

The method proposed here allows to predict barley quality, anthocyanin, β-glucan and water contents in the harvested "Daishimochi" of barley grains before the harvest. Through experiment, it is found that the barley quality can be predicted before the harvest with high R^2 value (more than 0.99). Therefore, it is possible to control fertilizer and water supplies before the harvest.

B. Related Research Works

Regressive analysis on leaf nitrogen content and near infrared reflectance and its application to agricultural farm monitoring with helicopter mounted near infrared camera is proposed [1]. Also, effect of sensitivity improvement of visible to near infrared digital cameras on NDVI measurement in particular for agricultural field monitoring is proposed [2]. On the other hand, smartphone image based agricultural product quality and harvest amount prediction method is proposed and validated [3].

A computer aided system for tropical leaf medicinal plant identification is attempted [4]. Meanwhile, product amount and quality monitoring in agricultural fields with remote sensing satellite and radio-control helicopter is proposed and evaluated [5]. On the other hand, computer vision for remote sensing is lectured in the Special Lecture on Computer Vision for Remote Sensing of Agriculture [6] together with Remote Sensing for Agriculture [7].

Intelligent system for agricultural field monitoring is proposed and realized [8]. Also, multi-level observation system for agricultural field monitoring is recommended [9] together with multi-layer observation for agricultural field monitoring [10]. On the other hand, another intelligent system for agricultural field monitoring is systemized and realized [11].

Another multi-level observation system for agricultural field monitoring is presented [12] together with multi-layer observation for agricultural field monitoring [13]. Meanwhile, another multi-layer observation for agricultural (tea and rice) field monitoring is realized and evaluated its performance [14]. bigdata platform for agricultural field monitoring and environmental monitoring is presented for global monitoring particularly [15].

Degree of polarization model for leaves and discrimination between pea and rice types leaves for estimation of leaf area index is investigated [16]. Also, nitrogen content estimation of rice crop based on Near Infrared (NIR) reflectance using Artificial Neural Network (ANN) is proposed [17]. On the other hand, effect of stump density, fertilizer on rice crop quality and harvest amount in 2015 investigated with drone mounted NIR camera data is evaluated [18].

Relation between rice crop quality (protein content) and fertilizer amount as well as rice stump density derived from helicopter data is investigated [19] together with estimation of rice crop quality and harvest amount from helicopter mounted NIR camera data and remote sensing satellite data [20].

Method for NIR reflectance estimation with visible camera data based on regression for NDVI estimation and its application for insect damage detection of rice paddy fields is proposed [21]. Meanwhile, artificial intelligence based fertilizer control for improvement of rice quality and harvest amount is proposed and well reported [22].

III. Proposed Method

The method proposed here allows to predict barley quality, anthocyanin, β-glucan and water contents in the harvested "Daishimochi" of barley grains before the harvest. Using the results from the regressive analysis with UAV mounted NIR camera data and chemical content measurements about anthocyanin, β-glucan and water contents in the harvested barley crops, it is possible to predict these contents with the UAV mounted NIR camera data acquired in the future.

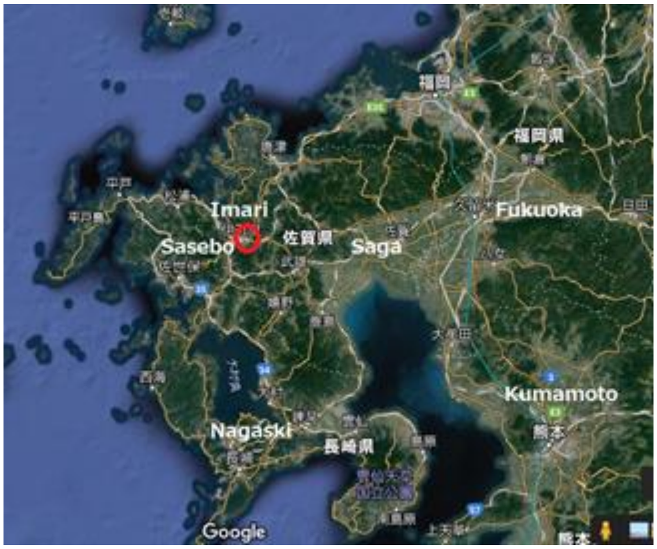
IV. Experiment

A. Intensive Study Area

The intensive study area is situated Kisu, Imari City, Saga in Kyushu, Japan (33:29N, 129:86E) sown in Fig. 1.

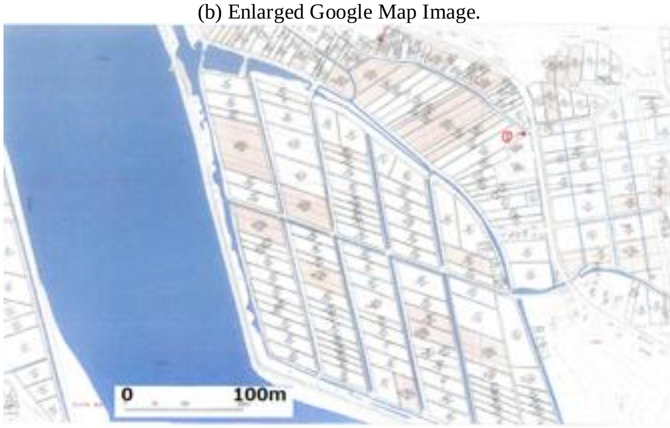
The late of November to the begging of December in 2018, Daishimochi of barley is planted in the intensive study farm areas. After the fundamental fertilizer is supplied, barley trampling is conducted a couple of time. Then additional fertilizer is put in the farm areas. Afterall Daishimochi barley is harvested in May 2019.

Fig. 2(a) shows photos of the scenery of the farm area just before the harvest while Fig. 2(b) shows the outlook of the harvested Daishimochi barley grains. Approximately, one month before the harvest, the farm areas are observed by the UAV mounted NIR camera (Fig. 2(c)).



(a) Kisu Town in Imari City (Red Circle).

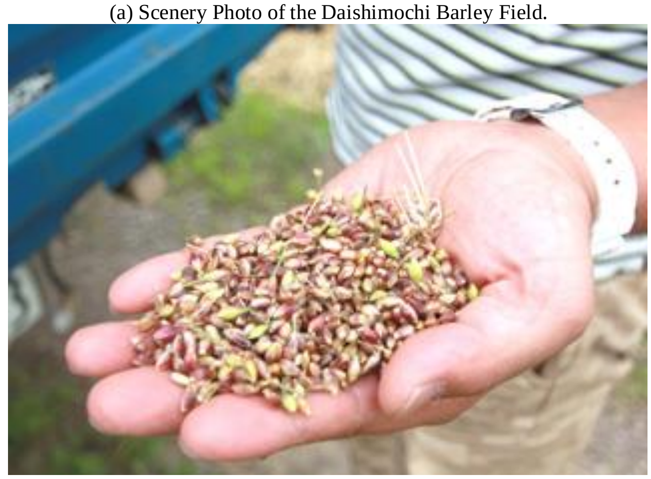
(b) Enlarged Google Map Image.



(c) Location of Intensive Study Area (Red Circle).

Fig. 1. Intensive Study Area.

(a) Scenery Photo of the Daishimochi Barley Field.



(b) Outlook of the Harvested Daishimochi Barley Grains.

(c) UAV Carrying NIR Camera.

Fig. 2. Phtos of Daishimochi Berley Field and the Harvested Grains and the Outlook of the UAV Carrying NIR Camera.

B. Acquired NIR Images of the Daishimochi Barley Fields

During the NIR image acquisition with UAV mounted NIR camera, standard plaque is put on the Daishimochi barley fields (1), (2), (3) and (4). Fig. 3 shows the acquired images of the fields. Meanwhile, close-up NIR images of standard plaque and the Daishimochi barley of the fields (1), (2), (3) and (4) are shown in Fig. 4. Standard plaques for each field are marked with yellow circles in Fig. 4. The NIR images and histograms of the standard plaque and Daishimochi barley of the field #1 are shown in Fig. 4(a) and (b), respectively while those of the field #2 are shown in Fig. 4(c) and (d). On the other hand, those of the field #3 are shown in Fig. 4(e) and (f) while those of the field #4 are shown in Fig. 4(g) and (h), respectively.

C. Chemical Composition Analysis

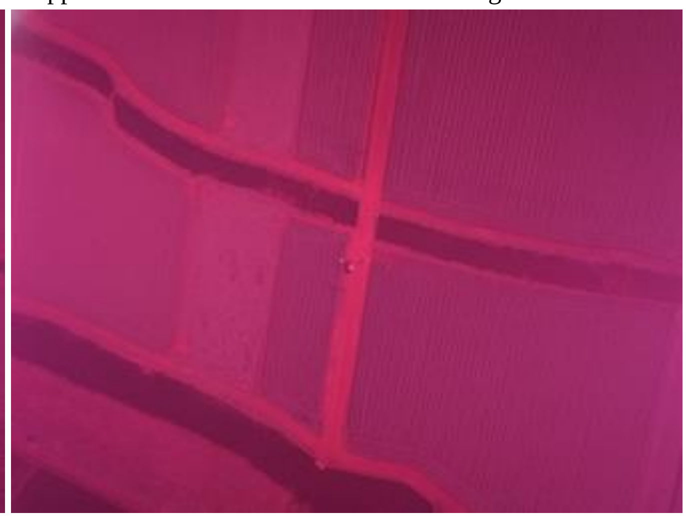
Chemical composition analysis is made for the harvested Daishimochi barley grains from the fields #1, #2, #3, and #4. As the chemical composition, water content (%), Anthocyanin content (mg Cy3G/100 g), Anthocyanin content (mg Cy3G/100 g: which corresponds to dry matter), and barley β-glucan (%) are selected because these factors are significant specific feature of the Daishimochi barley grains. The results are shown in Table I.

In the table, the mean of the acquired NIR reflectance is also shown. There is strong positive correlation between NIR reflectance and water content obviously while there is negative correlation between NIR reflectance and Anthocyanin content as well as Anthocyanin (corresponding to dry matter). On the other hand, there is positive correlation between barley β-glucan and NIR reflectance as shown in Table I.

D. Regression Analysis

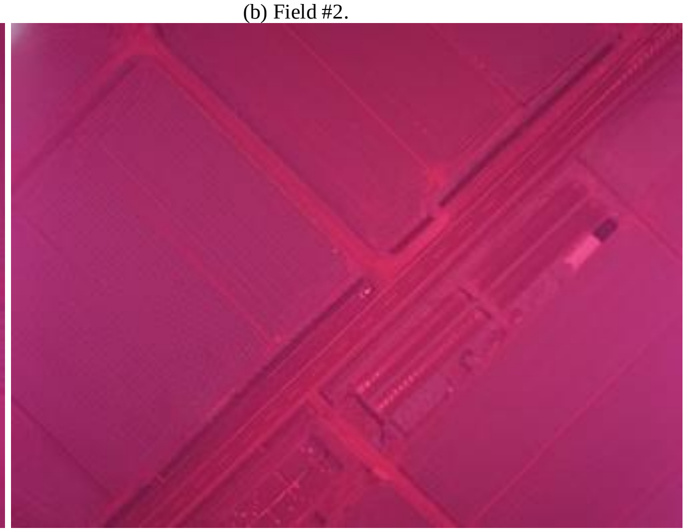
Regression analysis is made among NIR reflectance and Water content, barley β-glucan, Anthocyanin content as well as Anthocyanin (corresponding to dry matter) with linear approximation. The results are shown in Fig. 5.

(a) Field #1.



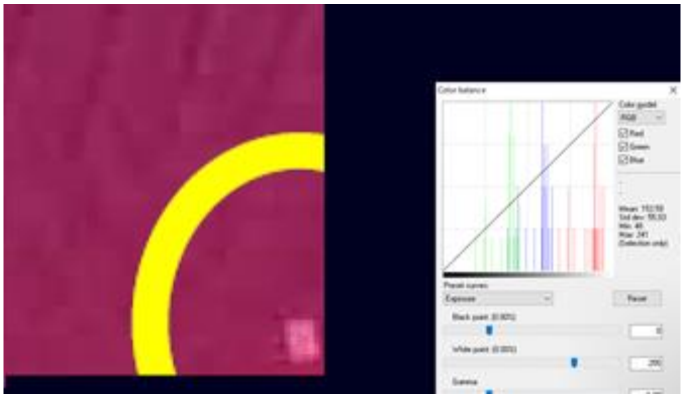
(b) Field #2.

(c) Field #3.

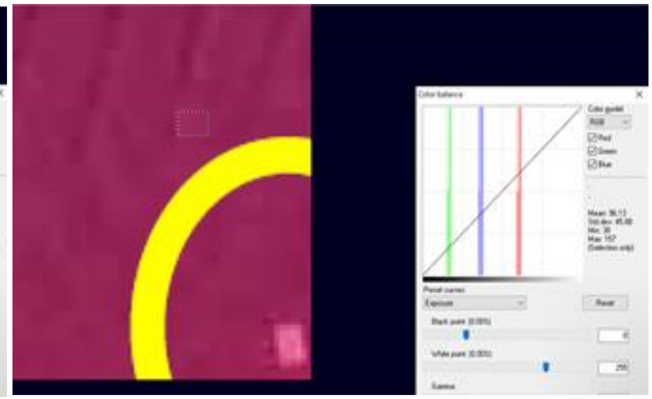


(d) Field #4.

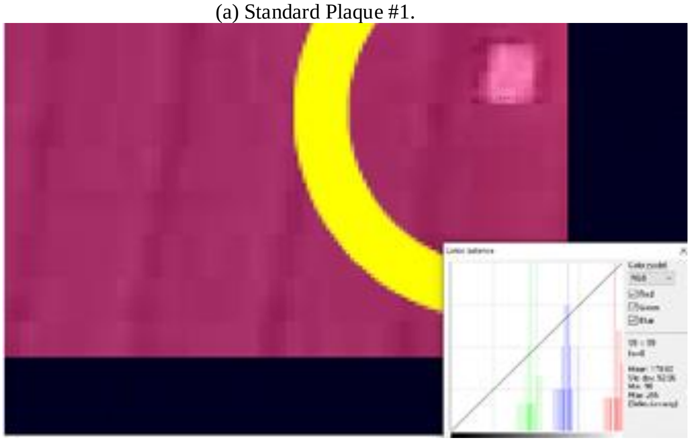
Fig. 3. Acquired NIR Images of the Daishimochi Barley Fields.



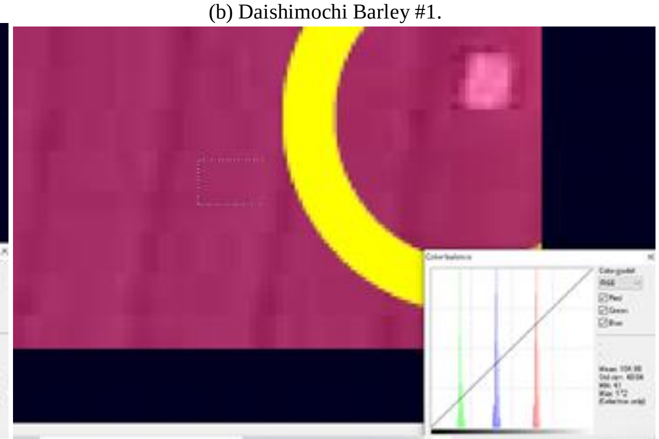
(a) Standard Plaque #1.



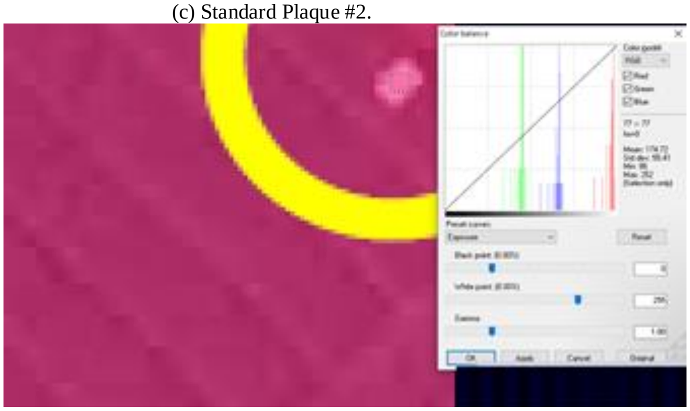
(b) Daishimochi Barley #1.



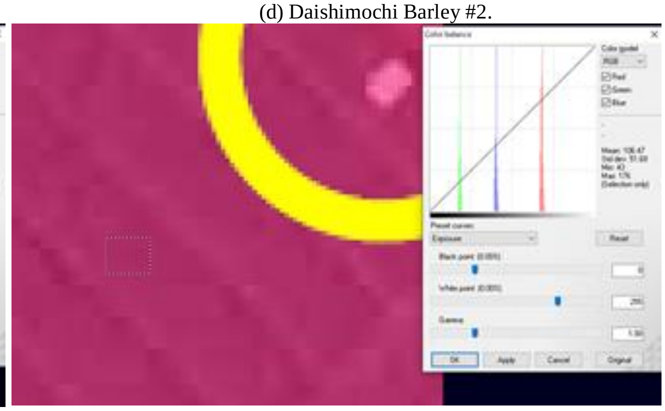
(c) Standard Plaque #2.



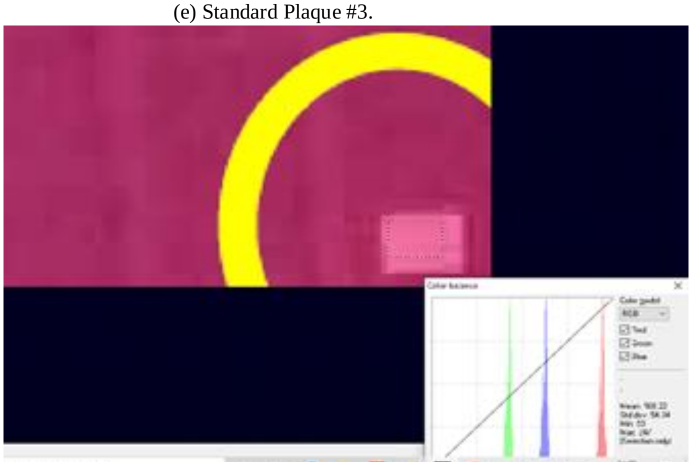
(d) Daishimochi Barley #2.



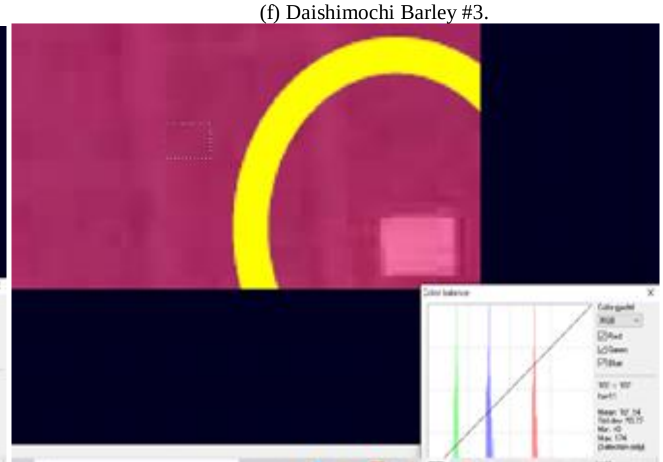
(e) Standard Plaque #3.



(f) Daishimochi Barley #3.



(g) Standard Plaque #4.



(h) Daishimochi Barley #4.

Fig. 4. Acquired NIR Images and Histograms of each Daishimochi Barley Fields and Standard Plaques.

TABLE I. NIR REFLECTANCE, WATER CONTENT

Field	NIR Ref.	Water content	Anthocyanin	Anthocyanin(D)	barley β-glucan
#1	0.6259	12.8	3.1	3.6	5.1
#2	0.5891	12.5	9.1	10.5	3.2
#3	0.6094	12.6	6.9	7.9	
#4	0.6036	12.6	6.5	7.4	

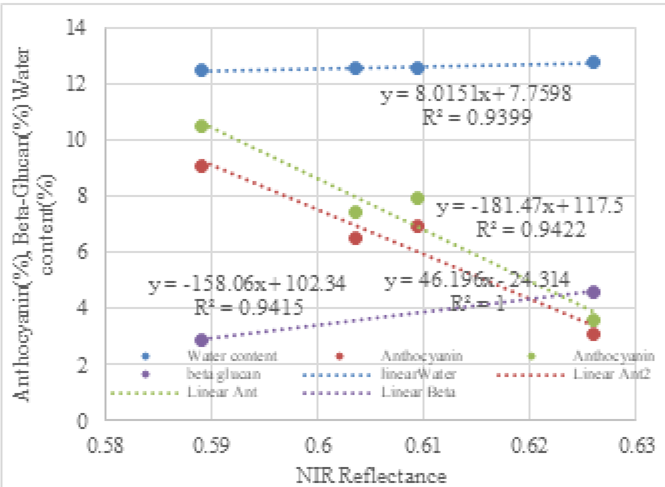


Fig. 5. Results from the Regressive Analysis among NIR Reflectance and Water Content, Barley β-glucan, Anthocyanin Content as well as Anthocyanin (Corresponding to Dry Matter) with Linear Approximation.

As the results, the following calibration curves (linear regressive equations) are obtained.

$$y_w = 8.0151x_w + 7.7598 \quad (1)$$

$$y_a = -181.47x_a + 117.5 \quad (2)$$

$$y_{ad} = -158.06x_{ad} + 102.3 \quad (3)$$

$$y_g = 46.196x_g - 24.314 \quad (4)$$

where y_w and x_w are water content and NIR reflectance while y_a and x_a are Anthocyanin content and NIR reflectance. Meanwhile, y_{ad} and x_{ad} are Anthocyanin content (corresponding to dry matter) and NIR reflectance while y_g and x_g are barley β-glucan and NIR reflectance, respectively. Thus it is found that water content (%), Anthocyanin content (mg Cy3G/100 g), Anthocyanin content (mg Cy3G/100 g: which corresponds to dry matter), and barley β-glucan (%) can be predicted before the harvest. Therefore, farmers can control fertilizer and water supply for improvement of the Daishimochi barley grain quality.

V. CONCLUSION

Barley quality estimation method with Unmanned Aerial Vehicle: UAV based Near Infrared: NIR camera data based on regressive analysis is proposed. The proposed method allows to predict barley quality, anthocyanin, β-glucan and water contents in the harvested “Daishimochi” of barley grains before the harvest.

Through experiment, it is found that Daishimochi barley grain quality, water content (%), Anthocyanin content (mg Cy3G/100 g), Anthocyanin content (mg Cy3G/100 g: which corresponds to dry matter), and barley β-glucan (%) can be predicted before the harvest. Therefore, farmers can control fertilizer and water supply for improvement of the Daishimochi barley grain quality.

VI. FUTURE RESEARCH WORKS

The proposed method has to be validated with the other types of agricultural products. Also, further experiments with drone mounted NIR camera data are required for validation of the proposed method.

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Enterprise Architecture "As-Is" Analysis for Competitive Advantage

A Case Study of the Internet Service Provider Company

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***Abstract*—In the telecommunication market, it is essential to ensure that the infrastructure and resources of the internet service provider can adapt and grow. In contrast, provide the best quality of data services and offering the best packages for their customers. It is essential to ensure that an internet service provider company remain competitive and agile so that it can provide better products and services promptly to the market. At iiNET, raising awareness of how having an enterprise-wide understanding and view of how the business processes run and all the existing technology within the organisation is vital in ensuring their adaptability and growth in the telecom industry. This paper discusses the challenges which IINET is currently facing and how an enterprise architecture solution is proposed to provide iiNET with the strategic advantage it needs to overcome those challenges. The existing EA frameworks are discussed and analysed to select the best fit for iiNET's EA solution. Finally, the "As-Is" architecture at iiNET is explained as the findings for this EA implementation phase.**

***Keywords*—Enterprise architecture; internet service provider; competitive advantage; "As-Is" analysis**

I. Introduction

Today, technology has enabled a fast-paced environment where integration between business and systems has become an essential part of an organisation's success. Technology has allowed for a much higher level of integration between old and new architectures, to support all levels of functions in a business [1]. The problem that is currently faced is that there is clear segregation between the IT implementation in an organisation and its department. Each department is either using their own isolated IS or not at all. This often causes a weak communication between communications between departments as well with systems outside the organisation [2].

The top telecommunication leaders in the industry can achieve this because, they have a clear understanding of data flows in the organisation, applications capabilities and infrastructure across of their business units [3]. That is, they, at all times, have a precise enterprise-wide view of the business, operations and all the technologies underlying it. This can be achieved by forming competitive advantage strategies that allow a company to produce goods or services better or more cheaply than its rivals. The competitive advantage is linked to a variety of factors, including pricing structure, brand marketing, product quality, customer base, intellectual property and customer care. To build an impactful competitive advantage strategy, it often combines with competitive intelligence that refers to the ability to collect, evaluate and use the knowledge gathered about rivals, consumers and other market factors [4]. This is where it can be synergised with Enterprise Architecture (EA) as it aligns the organisations business process to its strategic goals and supported by its technologies.

EA is a holistic strategy that is used to increase the alignment of the enterprise's business and Information Technology [5]. EA gives a blueprint for creating enterprise-wide information systems" to achieve its business objectives systematically. There exist different frameworks of EA application, all mainly consist of the following four main layers: business, data, applications and technology infrastructure. These layers describe how the information systems, processes, organisational units and people in an organisation function as a whole. EA ensures that the layers are integrated to drive the organisation's strategic goals, ensuring alignment between business and IT.

Ultimately, EA is a systematic structure or taxonomy of system analysis models to match organisational strategy with IT. However, EA implementation is not an easy process, as it requires support from both business and IT personnel[6]. There is resistance towards EA implementation from management as well as employees due to unclear expectation. In some cases, EA implementation becomes ineffective due to the complexity associated with EA implementations of practices, models and strategy. Due to this increased complexity and failing to realise the benefits that EA brings it causes a lack of support from shareholders and failure to accept and change.

This paper will describe the role of competitive advantage and competitive intelligence strategy in EA implementation at a large internet service provided company. The scope of this paper is on the EA design process, and it will explain how they are mapped together. At the end of the paper, the "As-Is" architecture findings of the case study are presented.

II. Literature Review

EA is a blueprint for identifying the structure and functioning of organisations with an extensive framework or taxonomy for system analysis models to align organisational strategy with IT. There are many EA frameworks exists according to the need of the organisation, and among the widely adopted structures are TOGAF, Zachman EA Framework and EA3Cube, which will be described in the following subsections

A. Enterprise Architecture Framework

1) The Open Group Architecture Framework (TOGAF): TOGAF is a framework which focuses on Enterprise Continuum with the Architecture Development Method (ADM). It was developed in 1995 by The Open Group. TOGAF is an open-source framework. It provided an organisation with the tools and methods needed to build Enterprise architecture [7]. There are several strengths of TOGAF that attracts much organisation to adopt this framework for their EA implementation. Some of the strength is; TOGAF allows a cost-efficient way for any organisation to implement EA as it uses a simplified approach to design, plan, acquire, and integrate the IT architecture to the business. It is flexible and adaptable and more practical to use than other existing framework solutions. TOGAF is also an open framework and freely accessible to anyone. Another advantage of TOGAF is, it is supported by a large community which portrays the credibility of the framework itself.

However, there is are also some limitation of TOGAF as discussed by previous studies. Firstly, TOGAF is not tightly integrated, and the existing material is comprehensive [8]. Despite being public, there are not many available TOGAF implementations freely available as it is considered the company privacy asset [9]. It can be vague and not as prescriptive and measurable. Therefore, this makes it harder to implement, especially for the beginner[10]. Thus, in many cases, experienced enterprise architects are needed to design such frameworks, as there is still scarce of guidance available, especially for the solution architects role.

2) The zachman framework: The Zachman framework, despite its name, is less of a framework and more of an ontology used in the structure of an EA. This ontology provided a formal and structured way of and defining an enterprise and has been employed in many large organisations, and proven to work by Zachman's experience himself [11]. The Zachman framework(ontology) is made up of a two-dimensional classification schema or a 2x2 matrix that reflects the intersection between two historical classifications [11]. The first is rudimentary: data (what), function (how), network (were), people (who), time (when) and motivation (why). The second is the ontological principle of reification, the conversion of an abstract idea into an instantiation. The transformations under Zachman Framework are description, concept, representation, specification, configuration and instantiation of what, how, who, when, and why in the designing of information system roles (or perspectives). The Zachman framework reification transformations are identification, definition, representation, specification, configuration and instantiation of the what, how, where, who, when and the why based on the roles (or perspectives) involved in information systems design [11].

Based on previous studies, the strength of the Zachman framework is that it allows different stakeholders ranging from business until technical personnel to look at the same thing from different perspectives [12, 13]. Thus, it efficiently creates a holistic view of the environment. This framework also is an excellent tool for determining the taxonomy of an enterprise [14]. Nevertheless, the Zachman framework also has some significant drawback, such as no step-by-step procedure for creating a new architecture, which resulted lost in the architecting process[15]. Furthermore, there is a lack of analysis to validate either the proposed future architecture is improving the current architecture[16]. Therefore, it falls short at prescribing detailed solutions for enterprise problems and often implies solutions that are too idealistic and less realistic.

3) EA3 cube framework: EA cube is a framework explaining the different components and layers within the framework. Scott Bernard created the EA 3 Cube in 2004, and iEAi owns EA3 [17]. It is based on the concept: "EA=Strategy+Business+Technology"; whereby the purpose of EA3 Cube framework is to transform an enterprise from its current state to a future desired state. The five layers in EA3Cube are: 1) Goals and Initiatives, 2) Products and services, 3) Data and Information, 4) Systems and Applications, 5) Networks and Infrastructure[17].

Previous studies highlighted some positive remarks on EA3Cube as this framework uses EA's primary organising and planning IT resources and documentation. It will also still comply with the organisation's vision [18]. Another advantage is that it is a simple framework and can be easily applied [19]. Meanwhile, there is also a limitation of EA3Cube as it is more suited to be used by small and medium-sized organisations compared to the large organisation [20]. Since it is also a proprietary framework, the cost of maintaining the current infrastructure can be a liability [15].

B. Competitive Advantage Concept

Competitive advantage applies to conditions enabling a business to manufacture products or services more or cheaper than its competitors. These factors allow a competitive company to produce more revenue or profits than its industry rivals [21]. Competitive advantages are attributed to various factors, including cost structure, branding, product quality, distribution network, intellectual property, and customer service [22]. Due to specific strengths or conditions, competitive advantages generate higher value for a firm and its shareholders. The more sustainable the competitive advantage, the harder it is for competitors to neutralise the advantage.

Competitive intelligence refers to the ability to collect, interpret and use the information on rivals, consumers and other market indicators that contribute to the competitive advantage of a company [23]. Economic knowledge is crucial because it lets firms understand their strategic climate and the prospects and challenges, hence allow businesses to analyse information for efficient business practices [24]. Competitive intelligence can be grouped into two main silos: tactical and strategic. Tactical intelligence is short-term and seeks to contribute to issues like capturing market share or increasing revenue. Meanwhile, strategic intelligence focuses on long-term issues like key risks and business opportunities.

C. Case Study Background

iiNET is a telecom company based in Australia which provides internet access services. Over the past couple of years, iiNET has lost 15% of its business profitability and facing many challenges it retaining its customers. The shareholders have been placing much pressure on the CEO of iiNET to make a change to the organisation to gain a strategic advantage over its competitors. Thus, the CEO tool the initiative along with the top management to look into an EA solution to align business and IT for competitive advantage in the marketplace [25]. Reports at iiNET revealed that due to inefficient business processes and IT infrastructure that could not keep up with the market internet access services provided.

The challenges that iiNET is facing include: 1) Losing customers to other new rise-up telecom companies; 2) Inefficient operations causing the lack of meeting the business goals; 3) The different network locations are not well maintained in some locations creating bad service as some locations.; 4) Other telecoms offering much faster data service and 5)Urgent need for an updated architecture that is robust enough to handle continued growth and can meet the needs of future regulatory requirements. To resolve these uprising issues, iiNET wants an enterprise solution which will help the organisation build the necessary strategic capability to allow it to gain a competitive advantage in the market. Through this implementation, iiNET is looking forward to introducing a method and tool that will guide in defining and governing their implementation while having a connected repository of the EA.

III. EA Design Methodology

In the initial stage, to choose the right EA framework, a study of the existing EA framework is done to evaluate the strength and weakness of each of the frameworks. In the second stage, a SWOT analysis is used to identify the strengths and weaknesses of the organisation which will help in choosing the right EA framework for the right situation and understand the strategic, political, innovation and cultural factors at iiNET. Once the study has been made, and analysis of the feasibility of the EA frameworks is done by using the result of the SWOT analysis as it helps understand the people, processes and technologies at iiNET and to select the most effective framework to support that. Fig. 1 shows the SWOT analysis performed at iiNET in choosing the suitable EA framework for implementation.

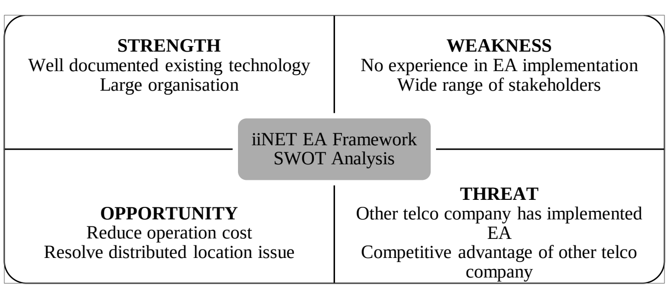

Fig. 1. iiNET EA Framework SWOT Analysis.

The strategy at iiNET is to reduce costs and document existing technologies to understand where to improve. Strategically, iiNET is concerned with aligning its business and IT operations and infrastructure to improve its service quality. Because iiNET has never implemented EA practices in the organisation before, it is essential to select an EA framework that not only provides a definition and conceptualisation of the framework but will provide a complete and detailed process to guide them into how to implement and know what to do next. It is also essential to select an EA framework that has been proven in the Telco industry to be a success for the organisation with no history of EA implementation and is just starting.

After evaluating the above frameworks, and reviewing the organisation's strength and weaknesses, the best fit selected to be used at the EA framework is the TOGAF framework used to build a successful architecture by iiNET to achieve rapid EA development utilising a cost-effective way. TOGAF has a set of defined approaches used to propose and direct the methodology and architecture. The next section will further describe how TOGAF is used to analyse the existing ("As-Is") architecture layers at iiNET.

IV. Results and Discussions

Based on a study by [26], every layer in EA can be aligned with a competitive advantage. Both EA and competitive advantage support the same vision and mission of the organisation. The relationship between competitive advantage, competitive intelligence and EA is shown in Fig. 2. Following, the "As-Is" findings in iiNET will be discussed according to Fig. 2.

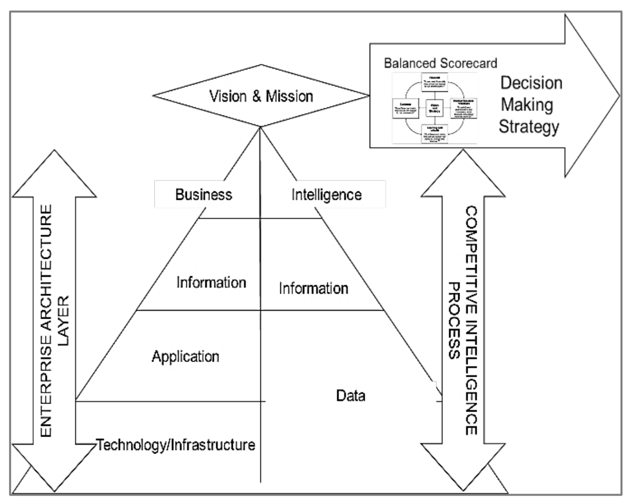

Fig. 2. The Relationship between EA and Competitive Advantage/Intelligence [26].

A. Business Architecture

iiNET's vision is to become the leading telco company for internet data services in Australia. The goal is to be the leader in providing the fastest and most stable internet accessibility. Initially, iiNET can provide internet services to its customer, which at the time was considered sufficient. However, the telco industry has grown over the years, with many new entrants offer better and faster internet services. For iiNET to compete, it needed to match up to that be provide even better services for customers. In iiNET, the main business functions which need to be aligned together are the customer relationship management, the telecom network resource management and lastly the partner relationship management. Aligning the above ensures the delivery of better internet data services using a systematic and efficient delivery model, ensuring service quality for customers.

Currently, iiNET is facing many challenges in its telecom network management. It is not able to maintain the infrastructure needed to provide internet networks for its customers. This resulted in service outages as well as slowness with caused much dissatisfaction in the customers. To tackle this challenge, the EA solution provided will bring value from each of the business processes. This is done through aligning iiNET's vision to its goals. When updating the goals and initiatives, value (including ROI) is defined in each of the business processes, and the reference architecture, which provides a template architecture and a common vocabulary is developed. This is to provide a common language that will be used to address all levels of the architecture.

B. Data Architecture

iiNET has been using the traditional commonly used Operational and Business Support Systems (OSS/BSS) for managing the business processes. These systems required much data gathering and shared data to serve the customers. The issue with these systems is that they have an existing integrating technology that makes it difficult to communicate with the data and result in much work to standardise data and information as it has their collection of data types and format, so a transition model was thus required to turn information and data into a unified framework. This resulted in much time consumed to do basic reporting and to understand and analyse the data reported. This made data inconsistent at some stages, which resulted in inaccurate data reaching the stakeholders at iiNET. Without accurate data, iiNET is unable to evaluate their finances and business process measures correctly.

On the data architecture layer, the EA solution provided offers a standardised data collection, storage and reporting tools for gathering and modelling data from all levels of the EA and stored it a common repository for access when needed. This ensures the data quality and consistency, and infrastructure optimisation with a greater emphasis on business integration. The EA solution offers EA process artefacts and standardised templates for reporting as well as metrics and performance measurement for reporting.

C. Application Architecture

iiNET's conventional OSS/BSS covers all operating systems used by internet service providers to control Billing Support Systems (BSS) telco network. This includes all systems dealing with customer service and maintaining customer relationships providing services like bill processing, payment collection, among others. These systems can no longer satisfy the TSP's need to deliver new value-added services or service bundles at a rapid pace to fight churn and ensure higher average revenue per user. iiNETS new OSS / BSS platforms are expected to leverage several architectures and networks and provide different services, including data-driven service scoring, billing and customer care.

With the EA solution offers an integrated OSS/BSS systems solution. This is done by using an integrated application queue based upon the standardised business processes. The customer relationship management system, telecom network resource management system and partner relationship management system are all integrated as one pool of systems, and it is using connectors to link to an integrated system application view. This means that employees only need to access the one systems to be able to access the services of underlying integrated systems. This solution also offers a customer-facing web application for processing subscription, billing, payments processes and more.

D. Technology Architecture

Initially, these traditional OSS/BSS systems were mainframe-based, stand-alone systems designed to support staff members in their daily jobs. This posed a problem that a minor improvement in one device might affect all interfaces. This significantly increased the complexity of the systems. Furthermore, iiNET's existing network infrastructure that is distributed across the different location is not well maintained. iiNET is unable to keep track of the infrastructure management process.

Fig. 3 shows the overall EA "As-Is" findings for iiNET as discussed.

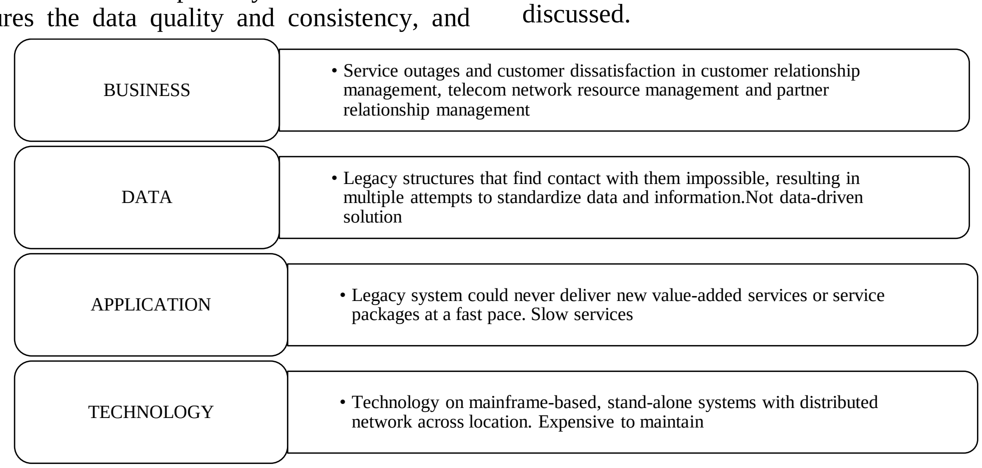

Fig. 3. EA based "As-Is" Findings for iiNET.

The EA "As-Is" analysis and framework mapping allow the identification of the right supporting technologies required the various systems in iiNET. Currently, the solution used for gathering and defining all IT related domains and assets related to business processes were captured in IBM Rational System Architect Platform, which later can be translated into a new "To-Be" architecture of iiNET.

To validate the findings, a set of questions were designed for the respondents from various departments across the iiNET that involved in this "As-Is" data collection. There are six questions asked, with the Likert scale 1 to 5 (1-strongly disagree to 5-strongly agree):

1) Do you agree.with the overall "As-Is" findings?
2) Do you agree.with the Business "As-Is" findings?
3) Do you agree.with the Data "As-Is" findings?
4) Do you agree.with the Application "As-Is" findings?
5) Do you agree.with the Technology "As-Is" findings?
6) Do you agree.with that this "As-Is" findings able to highlight the existing competitive advantage/intelligence??

A total of 26 responds were collected from the survey. The validation results stated that the mean for each question are between 3.96 until 4.56 which indicates that the "As-Is" findings are valid and can be used for the next stage, which is "To-Be" phase.

With the future EA solution, the strategic mapping and compliance can also be carried out to determine the level of standardisation and optimisation of the resources in a large organisation like iiNET. Furthermore, with well-defined architecture principles that were derived from competitive advantage, exercise will be able to revise the existing business process and introduce several new initiatives with minimal efforts.

V. Conclusion

With the current state that iiNET was in, they required an enterprise architecture solution which out helps them overcome the challenged that was causing them to fall behind in the telecom industry. Using the TOGAF framework, an EA solution was designed, providing a description blueprint of the business, data, application, and technology architectures at iiNET. Not only is the EA solution providing next-generation solutions, but it has also allowed iiNET to use its existing legacy systems, modifying them, and integrating them other systems in the ways needed to meet their needs.

For future works, it is suggested to design a "to-be" solution that utilized on the module-based connector solution. This will provide an integrated solution for fulfilling all business processes when changes are made in any of the modules, they quickly integrated into system layer, ensuring that systems running below are not affected. In conclusion, for iiNET to continue to grow in the telecom industry, it must ensure that it has a thorough understanding of all its business processes and IT landscape to ensure that their technology and application infrastructure is aligned with and meetings the business goals.

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A Novel ASCII Code-based Polybius Square Alphabet Sequencer as Enhanced Cryptographic Cipher for Cyber Security Protection (APSAlpS-3CS)

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***Abstract*—For all industries, cybersecurity is regarded as one of the major areas of concern that needs to be addressed. Data and information in all forms should be safeguarded to avoid leakage of information, data theft, and robbery through intruders and hackers. This paper proposes a modification on the traditional 5x5 Polybius square in cryptography, through dynamically generated matrices. The modification is done through shifting cell elements for every encrypted character using a secret key and its ASCII decimal code equivalents. The results of the study revealed that the modified Polybius cipher offers a more secure plaintext-ciphertext conversion and is difficult to break, as evident in the frequency analysis. In the proposed method, each element produced in the digraphs exhibits a wider range of possible values. However, with the increase of process in the encryption and decryption, the modified Polybius cipher obtained a longer execution time of 0.0031ms, being identified as its tradeoff. The unmodified Polybius cipher, however, obtained an execution time of 0.0005ms. Future researchers may address the execution time tradeoff of the modified Polybius cipher.**

***Keywords*—Cryptography; ciphers; ciphertext; modified polybius cipher; plaintext**

I. Introduction

Cybersecurity has been the primary focus of all industries when it comes to communications security, as heterogeneous data needs to be safeguarded. As all industries leverage on the use of the internet, most of today's transactions are carried out online as a medium of communication since mobile devices and Wi-Fis are readily available. All forms of data ranging from public to private organizations of all sizes possess valuable information and are vulnerable to attacks. Subsequently, data security implementation is still an ongoing quest, and managing information technology (I.T) security has become a challenge due to factors such as the unavailability of experts and the cost involved. Therefore, security has been a concern of all industries as companies are on war against hackers and intruders [1].

Various researches in this area lobby the use of algorithms to address security issues and provide data and information security against hackers and intruders. Cryptography [2], being a known technique in communications security, deals with algorithms for security services to wit: confidentiality and integrity of data, authentication to a wireless communication system, and several other security protocols where information transfer is done between different users [3]–[5]. With extent to the data format such as text, the data protection is made through the use of encryption where conversion of the plaintext into an unintelligible format called ciphertext is done. To revert the ciphertext, a decryption process is done. A cipher algorithm is responsible for the encryption and decryption of the data [2]. Some of the classical ciphers found in the literature are ADFGX Cipher [6]–[8], Affine Cipher [8]–[11], Atbash Cipher [12], Auto-key Cipher [13], Baconian Cipher [8], [14], Base64 Cipher [15]–[17], Beaufort Cipher [8], Caesar Cipher [18]–[20], Enigma Machine Cipher [8], Four-square cipher [8], Grille Cipher [21], Hill cipher [22], Homophonic Substitution Cipher [23], [24], Permutation Cipher [8], Playfair Cipher [25]–[27], Polybius Cipher [28]–[32], and Rail fence Cipher [33], [34], among others.

Among these, the Polybius cipher, also known as the Polybius square, is one of the commonly used methods for cryptography [35], [36]. It is one of the early cryptographic systems developed for obscuring plaintext by fractionating and substituting numbers [37]. To date, the Polybius square is still extremely valuable for cryptographers. Its ability to convert letter sequences to numeric sequences, reduce the number of different characters, and allow encoding of plaintext into two separately manipulatable units are known to be its advantages [6], [38]. Further, the Polybius square has paved the way to the development and processes of other classical ciphers that are still used today such as ADFGVX Cipher [8], [39]–[41], Bifid cipher [8], [42], Nihilist cipher [43], and Trifid cipher [44], [35]. Furthermore, modern cryptographic systems have embedded the Polybius square as a fundamental component of the cryptographic process, such as in the key generation procedures used by modern ciphers like the advance encryption standard (AES), data encryption standard (DES), and other algorithms [2], [39], [40], [45]–[50].

However, the Polybius square is a substitution cipher that is susceptible to attacks and is easy to crack with frequency analysis due to the simplicity of element distribution within its grid [51]. This problem is rooted in the structure and elements within the square grid. Therefore, there is a need to introduce a new scheme for character sequencing before performing the substitution; thus, this study. The rest of the paper is structured as follows: Section II presents the literature review of existing methodology and modifications in the Polybius cipher. The proposed enhancement in the Polybius cipher is discussed in Section III, while Section IV presents the results and discussion. The conclusion is shown in Section V.

II. Literature Review

Cryptography [4] is one of the widely used obscuring techniques to protect data and is commonly used in various industries [52]–[55]. Communications security is ensured through the use of ciphers whose bottleneck for an optimal implementation relies on the cipher algorithm used for encryption and decryption process. The basic ciphers are categorized into two: the substitution and transpositions. A transposition cipher transposes or reorders elements such that elements in the first place of the plaintext may be positioned in any other place of the ciphertext. Likewise, an element in the seventh place of the plaintext may be positioned in the first place of the ciphertext [10]. Meanwhile, substitution ciphers is an encoding technique where characters in the plaintext are replaced with a character or symbol or both. Ciphers such as ADFG(V)X, Alberti cipher, Autokey cipher, Caesar cipher, Four-square cipher, Polybius cipher, Enigma cipher, Freemason cipher, Kamasutra cipher, Larrabee cipher, Monoalphabetic substitution cipher, and Pollux cipher takes a letter of an alphabet and substitutes it with another character [51].

The Polybius cipher, along with other Polybius-based ciphers, is continuously being utilized along with other modern cryptographic ciphers to improve services that involve and require text security protection in digital media, such as for online shopping, internet banking, chip operation, mobile cloud computing, and mobile messaging services [56], [49], [50].

A. The Traditional Polybius Cipher

Polybius cipher, known as Polybius square, is one of the early encryption systems recorded in the history that was developed by Greek historian and a soldier, Polybius [37]. Polybius square is a substitution cipher placed in a 5x5 grid matrix where the alphabet is arranged with corresponding rows and columns without repetition. As one of the earliest ciphers developed in history, its usage was early recorded as a medium of communication and used even in wars [35].

In the Polybius square, letters in the modern English alphabet comprising of 26 characters are placed in the 5x5 grid. Individual letters are spread all throughout the 25 cells in the matrix wherein characters J and I are combined as they share the same code [57]. The Polybius square with the English alphabet is shown in Table I.

Encryption and decryption using this technique are relatively easy because there is no need for a key. In encrypting plaintext, the characters are matched to the matrix one by one to retrieve their coordinates based on the intersection of row and columns. The set of coordinates generated represents the encrypted message. For example, encrypting the word CIPHER results to 1324352342, where character C is 13, I is 24, and so on. Table II shows the encryption result using the traditional Polybius square.

To decrypt a given ciphertext, the process is done in reverse. Each pair of numbers are compared to the matrix to translate the value to their corresponding plaintext form. In this case, the encrypted message 1324352342 is converted to CIPHER. Table III shows the encryption result using the traditional Polybius square.

Polybius cipher has been the basis of some of today's encryption methods. However, the Polybius square has its identified drawbacks. The cipher does not have a key for data encryption and decryption process making it vulnerable for cracks [34], [58]. Moreover, adding the characters I and J in one cell may cause complications to the original plaintext; hence, it may confuse the decoding process [47]. The ciphertext using the Polybius square is easy to decipher as characters are always represented as a pair.

The following sections discuss the modifications and hybridization made on the Polybius Cipher.

B. A Modified Polybius Square Based Approach for Enhancing Data Security

The study of [30] introduced a 6x6 grid Polybius square to include the English alphabet and numbers. In this square matrix, the numbers are first encoded, followed by the English alphabet, as shown in Table IV.

TABLE I. Polybius Square with the Modern English Alphabet

	1	2	3	4	5
1	A	B	C	D	E
2	F	G	H	I/J	K
3	L	M	N	O	P
4	Q	R	S	T	U
5	V	W	X	Y	Z

TABLE II. Encryption using Traditional Polybius Square

Plaintext	C	I	P	H	E	R
Position	1	2	3	4	5	6
Ciphertext	13	24	35	23	15	42

TABLE III. Decryption using Traditional Polybius Square

Ciphertext	13	24	35	23	15	42
Position	1	2	3	4	5	6
Plaintext	C	I	P	H	E	R

TABLE IV. Polybius Square with Digits

0	1	2	3	4	5
6	7	8	9	a	b
c	d	e	f	g	h
i	j	k	l	m	n
o	p	q	r	s	t
u	v	w	x	y	z

Techniques such as transposition, ring rotation, and row reversal are introduced to transmute the matrix. First, the grid performs row reversal by swapping the values in the row such that the 1st element becomes the 5th element, and is reciprocated. The same is applied for each remaining element in the row. For example, row 1 with elements 0|1|2|3|4|5 becomes 5|4|3|2|1 Table V shows the resulting elements' arrangement after applying row reversal.

The next process is the transposition, where values in each corresponding row are rewritten in columns. For example, row 1 with elements 5|4|3|2|1 is rewritten in column 1 with the same values. The new elements arrangement within the square grid after transposition is shown in Table VI.

Lastly, the matrix performs a rotation based on a given key. For example, with the given key as SASTRA, the key is used to retrieve the number of rotations by finding the sum of its ASCII values modulo length of the ring. Since the ASCII sum for the key is 654, the outermost ring is rotated by 14 times clockwise (654%20=14), while the second outermost ring and the inner ring is rotated 6 (654%12=6) and 2 (654%4=2) times, respectively. The grid matrix with new elements after the ring rotation is shown in Table VII.

After completing the processes, every character must be identified according to their relative coordinate in the new matrix and then crosschecked with the equivalent value in the original matrix using its coordinates. For instance, the element A in the new matrix is at coordinates (5,5); therefore, the plaintext is replaced with ciphertext S based on the given value in the same position from the original matrix. Table VIII shows the encryption result of the given key SASTRA.

C. An Extended Version of the Polybius Cipher

In the quest to include symbols and numbers in the Polybius square, the 5x5 grid from the traditional Polybius square matrix was expanded into an 8x8 grid matrix. With this expansion, a wide range of characters, symbols, and numbers have been used in encrypting messages. A keyword was also introduced to adjust the character's arrangement in the matrix. The keyword is placed on the top cells reaching the bottom and left to right cells of the grid without repetitions. Any remaining letters that are not used in the keyword are placed in the remaining cells in alphabetical order. Further, numbers are positioned in ascending order, followed by the special symbols arranged according to their ASCII value. Table IX shows how the extended Polybius square would appear using the keyword POLY2013 [47].

D. A Hybrid Polybius-Playfair Music Cipher

The paper [32] introduced a hybrid Polybius and Playfair cipher that translates plaintext into musical notes. To execute, the message is converted using Playfair digraphs and is encrypted with a key. The Polybius square with Playfair key labeled with five major music chords ABCDE is shown in Table X.

The generated ciphertext using the Playfair is re-encrypted using the Polybius square. The ciphertext is the musical equivalents of the Polybius cipher. Table XI shows how the string HELLO WORLD is encrypted using the hybrid technique. Performing the process in reverse order converts the ciphertext to the original plaintext by matching the chords with the generated matrix.

TABLE V. POLYBIUS SQUARE AFTER ROW REVERSAL PROCESS

5	4	3	2	1	0
b	a	9	8	7	6
h	g	f	e	d	c
n	m	l	k	j	i
t	s	r	q	p	o
z	t	x	w	v	u

TABLE VI. POLYBIUS SQUARE AFTER TRANSPOSITION PROCESS

5	b	h	n	t	z
4	a	g	m	s	y
3	9	f	l	r	x
2	8	e	k	q	w
1	7	d	j	p	v
0	6	c	i	o	u

TABLE VII. POLYBIUS SQUARE AFTER RING ROTATION PROCESS

Y	x	w	v	U	o
Z	p	j	d	7	i
T	q	k	e	8	c
N	r	l	f	9	6
H	s	m	g	A	0
B	5	4	3	2	1

TABLE VIII. ENCRYPTION USING THE MODIFIED POLYBIUS SQUARE

Plaintext	s	a	s	t	r	a
Coordinates	(5,2)	(5,5)	(5,2)	(3,1)	(4,2)	(5,5)
Ciphertext	p	s	p	c	j	s

TABLE IX. EXTENDED POLYBIUS SQUARE MATRIX

	1	2	3	4	5	6	7	8
1	P	O	L	Y	2	0	1	3
2	A	B	C	D	E	F	G	H
3	I	J	K	M	N	Q	R	S
4	T	U	V	W	X	Z	4	5
5	6	7	8	9		!	"	#
6	$	%	&	'	(	)	*	+
7	,	-	.	/	:	;	<	=
8	>	?	@	[	\	]	^	_

TABLE X. HYBRID POLYBIUS-PLAYFAIR KEY GRID MATRIX

	A	B	C	D	E
A	P	L	A	Y	F
B	I/J	R	B	C	D
C	E	G	H	K	M
D	N	O	Q	S	T
E	U	V	W	X	Z

TABLE XI. ENCRYPTION USING POLYBIUS-PLAYFAIR CIPHER

Plaintext	HELLO WORLD					
Playfair Digraphs	HE	LX	LO	WO	RL	DX
Playfair Cipher	KG	YV	RV	VQ	GR	ZC
Polybius Cipher	CDCB	ADEB	BBEB	EBDC	CBBB	EEBD

III. PROPOSED ENHANCED POLYBIUS CIPHER

In this study, the sequencing of the elements within the grid is modified. Instead of using the traditional character sequence in assigning coordinates as the ciphertext, the use of ASCII code to transmute the elements in the matrix with a secret key is introduced.

The enhanced polybius square (EPS) works by altering the arrangement of elements in the matrix based on the individual characters of a given key. For every character encrypted, a new matrix is used; therefore, similar plaintext letters may not have the same encryption value. This ensures that the ciphertext produced by the modified technique is always dynamic and more complicated to crack using frequency analysis.

The steps to encrypt a message using EPS is presented in Fig. 1, where detailed steps are as follows:

a) Identify a plaintext message and a secret key.

b) Each character from the secret key is paired with each of the plaintext characters. If the length of the secret key is less than the plaintext, it is paired repeatedly in a circular manner until the end of the plaintext length.

c) Take character n from the plaintext and its corresponding key pair.

d) Convert the key character to its ASCII decimal equivalent.

e) Perform a right shift to the elements of the Polybius Square based on the ASCII decimal equivalent.

f) Generate the ciphertext equivalent of character n using the transmuted matrix.

g) Repeat steps c to f until all characters in the plaintext are converted.

The steps to decrypt a message using EPS are presented in Fig. 2, where detailed steps are as follows:

a) Identify the ciphertext message and the secret key used.

b) Each character from the secret key is paired with each of the ciphertext digraphs. If the length of the secret key is less than the ciphertext, it is paired repeatedly in a circular manner until the end of the ciphertext length.

c) Take digraph n from the ciphertext and its corresponding key pair.

d) Convert the key character to its ASCII decimal equivalent.

e) Perform a right shift to the elements of the Polybius Square based on the ASCII decimal equivalent.

f) Generate the plaintext equivalent of digraph n using the transmuted matrix.

g) Repeat steps c to f until all digraphs in the ciphertext are converted.

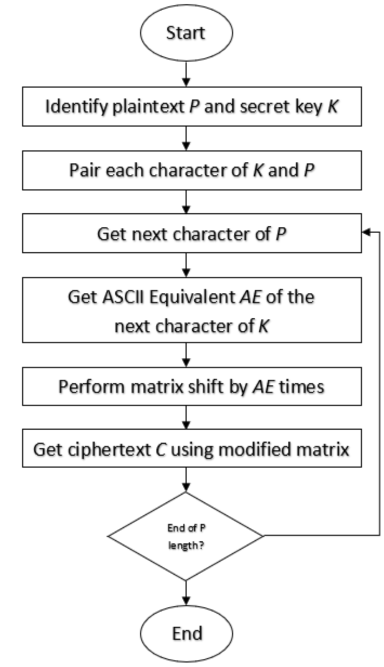

Fig. 1. Encryption Process

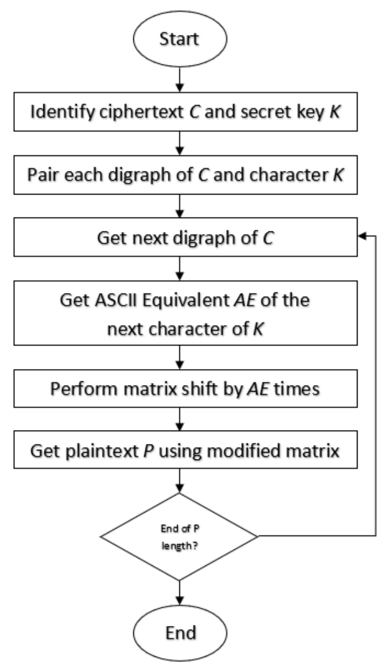

Fig. 2. Decryption Process.

IV. Results and Discussion

A. Enhanced Polybius Square Simulation Results

In this study, a simple program was created using Python 3 and was executed in an i7-7700HQ 2.80GHz 16GB RAM 4GB RAM laptop computer. First, the plaintext and a secret key are identified. Then, the secret key is matched for every character in the plaintext and repeated based on the length of the message. Next, the ASCII decimal code value is retrieved based on each of the characters in the secret key. The ASCII values are used to perform the number of shifts in the matrix elements to generate the code equivalent for each plaintext character. For example, the message POSSESSION with the secret key CARL and its corresponding ASCII decimal codes is shown in Table XII.

The matrix is first shifted 67 cells to the right, as shown in Table XIII, to encrypt the first character of the plaintext. The process produces a new matrix wherein character P is encoded as the ciphertext 22, as presented in Table XIV.

Next, the matrix is shifted again by 65 times based on the ASCII equivalent of the following secret key character A. With the new matrix, the plaintext character O is encoded as 51, as shown in Tables XV and XVI.

TABLE XII. Plaintext and Key with ASCII Equivalent

Plaintext	P	O	S	S	E	S	S	I	O	N
Key	C	A	R	L	C	A	R	L	C	A
ASCII Value	67	65	82	76	67	65	82	76	67	65

TABLE XIII. New Matrix after 1st Cell Shift

	1	2	3	4	5
1	I/J	K	L	M	N
2	O	P	Q	R	S
3	T	U	V	W	X
4	Y	Z	A	B	C
5	D	E	F	G	H

TABLE XIV. 1st Character Encryption using EPS

Plaintext	P	O	S	S	E	S	S	I	O	N
Key	C	A	R	L	C	A	R	L	C	A
ASCII Value	67	65	82	76	67	65	82	76	67	65
Ciphertext	22									

TABLE XV. New Matrix after 2nd Cell Shift

	1	2	3	4	5
1	T	U	V	W	X
2	Y	Z	A	B	C
3	D	E	F	G	H
4	I/J	K	L	M	N
5	O	P	Q	R	S

TABLE XVI. 2nd Character Encryption using EPS

Plaintext	P	O	S	S	E	S	S	I	O	N
Key	C	A	R	L	C	A	R	L	C	A
ASCII Value	67	65	82	76	67	65	82	76	67	65
Ciphertext	22	51								

The process is executed repeatedly until the end of the plaintext length. After all of the matrix shifts, the final ciphertext value is now regarded as 22 51 22 23 32 35 52 34 31 55, as presented in Table XVII.

The comparison between the traditional Polybius Square and the modified Polybius Square encryption using the same plaintext is shown in Table XVIII. Based on the results, it is evident that the ciphertext is entirely different from the result of the original technique. Also, depicted in the table are the encrypted values of repeating characters O and S. As observed, the traditional method uses the same substitution values for similar symbols, such that characters O and S are always replaced by 34 and 43, respectively.

On the other hand, the modified method produces a more varied ciphertext value, even for identical plaintext characters. As observed, no two similar characters have the same ciphertext equivalent. Also, having the same ciphertext values do not necessarily equate to being similar plaintext character. This denotes that even if the ciphertext is the same, they may not have equivalent plaintext value making frequency analysis and decryption even more confusing and complicated.

The decryption process requires access to the ciphertext and the secret key. Each character in the key is matched with every digraph in the ciphertext. This process is repeated based on the length of the encrypted message. Next, the ASCII decimal code value is retrieved based on each of the characters used in the key. The ASCII codes are used to perform the number of shifts in the matrix elements to retrieve the code equivalent for the ciphertext digraphs. The process is executed repeatedly until all digraphs are converted to their respective plaintext values. Table XIX shows the encrypted message 22 51 22 23 32 35 52 34 31 55 with the secret key CARL and its corresponding ASCII decimal codes.

As another example, the plaintext MISSISSIPPI is encrypted using the traditional and modified Polybius Square. The results are shown in Table XX.

The results manifest obvious patterns for the ciphertext values generated using the traditional method wherein the repeating values 24 for I, 43 for S, and 35 for P are shown several times. However, looking closely at the ciphertext produced by the Enhanced Polybius Square, it is apparent that no two same plaintext characters are encrypted identically. For example, the character S was substituted with the values 51, 14, 52, and 22. Also, having similar ciphertext codes does not necessarily mean they have the same plaintext values, such that the ciphertext 15 was used to substitute characters I and P.

B. Evaluation Method

In order to assess the effectiveness and efficiency of the proposed method for longer texts, the execution time is evaluated, and the frequency analysis is performed. Both modified and unmodified methods were developed and tested using the aforementioned environment.

The frequency analysis is used to predict the value of the ciphertext based on how often a character or code appears [37]. In order to test the proposed scheme through frequency analysis, a sample plaintext is first encrypted and then supplied to an online tool [59] from the website Dcode. The encrypted message is subjected to a digraphs-digits-only analysis. The following text was used for testing:

"thiscourseaimstoprovideyouwithdetailedknowledgeofimp ortanttechnologiesandapplicationthatareusedintheinternetdueto thebroadnatureofthisfieldthecoursecoversonlyselectedtopicsfo cussingfirstonsomeadvancedtopicsininternettechnologiesegwir elesslansmobileinternetmulticastandthenaselectionofcurrentan dnextgenerationapplicationsandservicesegppiptvvoip"

TABLE XVII. ENCRYPTED VALUES USING EPS

Plaintext	P	O	S	S	E	S	S	I	O	N
Key	C	A	R	L	C	A	R	L	C	A
ASCII Value	67	65	82	76	67	65	82	76	67	65
Ciphertext	22	51	22	23	32	35	52	34	31	55

TABLE XVIII. COMPARISON BETWEEN METHODS

Traditional Polybius Square										
Plaintext	P.	O.	S.	S.	E.	S.	S.	I.	O.	N.
Ciphertext	35	34	43	43	15	43	43	24	34	33
Enhanced Polybius Square										
Plaintext	P.	O.	S.	S.	E.	S.	S.	I.	O.	N.
Key	C	A	R	L	C	A	R	L	C	A
ASCII Value	67	65	82	76	67	65	82	76	67	65
Ciphertext	22	51	22	23	32	35	52	34	31	55

TABLE XIX. DECRYPTED VALUES USING EPS

Ciphertext	22	51	22	23	32	35	52	34	31	55
Key	C	A	R	L	C	A	R	L	C	A
ASCII Value	67	65	82	76	67	65	82	76	67	65
Plaintext	P.	O.	S.	S.	E.	S.	S.	I.	O.	N.

TABLE XX. COMPARISON USING REPEATED LETTERS

Traditional Polybius Square											
Plaintext	M	I	S	S	I	S	S	I	P	P	I
Ciphertext	32	24	43	43	24	43	43	24	35	35	24
Enhanced Polybius Square											
Plaintext	M	I	S	S	I	S	S	I	P	P	I
Key	U	S	U	S	U	S	U	S	U	S	U
ASCII Value	85	83	85	83	85	83	85	83	85	83	85
Ciphertext	52	12	51	14	15	52	22	21	52	15	24

Presented in Table XXI is the result of the frequency analysis of the encoded text using the traditional Polybius Square. Based on the result, the digraphs 15, 44, 24, 33, 34, 43, and 11 have the most count of repeating codes in the encrypted text. If these values are converted using the traditional method, the decrypted values would be E, T, I, N, O, S, A, respectively. The results adhere to the paper of [60] which discusses the top 7 most frequent letters in the Latin alphabet which are: E, A, T, I, O, N and S. This just means that a substitution cipher such as the Polybius Square is indeed prone to frequency analysis and therefore easy to break [2], [4], [34], [57].

Presented in Table XX is the result of the frequency analysis of the generated ciphertext using Enhanced Polybius Square. Based on the results, it is evident that there is minimal difference in the occurrence of each digraph. However, it can also be understood that decoding an EPS encoded message through frequency analysis may be very difficult and may take a long time since every digraphs or code can represent a number of plaintext values such that the digraphs 13 could mean any of the 25 letters depending on the series of transmutations on the matrix. Thus, making EPS not prone to frequency analysis.

TABLE XXI. FREQUENCY ANALYSIS RESULTS USING THE UNMODIFIED POLYBIUS SQUARE

Digraphs	**Frequency**	**%**
15	45	13.16
44	36	10.53
24	31	9.06
33	30	8.77
34	29	8.48
43	24	7.02
11	21	6.14
42	17	4.97
13	16	4.68
14	15	4.39
31	14	4.09
35	12	3.51
23	10	2.92
45	9	2.63
22	7	2.05
51	6	1.75
21	6	1.75
32	5	1.46
52	3	0.88
54	2	0.58
12	2	0.58
25	1	0.29
53	1	0.29

TABLE XXII. EPS FREQUENCY ANALYSIS RESULT

Digraphs	Frequency	%
13	21	6.14
45	20	5.85
54	20	5.85
31	18	5.26
15	18	5.26
23	17	4.97
11	17	4.97
25	15	4.39
35	15	4.39
51	15	4.39
22	13	3.8
14	13	3.8
24	13	3.8
21	13	3.8
41	12	3.51
43	12	3.51
33	12	3.51
34	12	3.51
42	12	3.51
52	12	3.51
12	11	3.22
55	8	2.34
44	8	2.34
52	8	2.34
32	7	2.05

With the extent to the processing time, it has been revealed that EPS has higher execution time with 0.0031s as compared to the unmodified method with 0.0005s. The results can be attributed to the fact that a new matrix is generated for every encrypted character against a static grid of the traditional Polybius Square. The simulation results are shown in Table XXIII.

With the use of the identified evaluation methods, the simulation results revealed that EPS performs better as the proposed method provides more layers of security through the use of a secret key and dynamically generated matrices.

TABLE XXIII. EXECUTION TIME INDEXED RESULTS

String:	MISSISSIPPI
Length:	11 characters
EPS Key:	US
Traditional P.S. Execution Time	0.003192900000000165 sec
EPS Execution Time	0.0005627999999999744 sec

V. CONCLUSION

This study presents a modification on the traditional Polybius Square through cell shifting and dynamic matrix generation using a keys' ASCII code. It has been revealed that the proposed method is more secure and is difficult to break via frequency analysis. However, the increase in security comes with a tradeoff in its execution time. It is recommended that further studies may be conducted to solve this problem.

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An Efficient Convolutional Neural Network for Paddy Leaf Disease and Pest Classification

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***Abstract*—Improving the quality and quantity of paddy production is very important since rice is the most consumed staple food for billion people around the world. Early detection of the paddy diseases and pests at different stages of growth is very crucial in paddy production. However, the current manual method in detecting and classifying the paddy diseases and pests requires a very knowledgeable farmer and time consuming. Thus, this study attempts to utilize an effective image processing and machine learning technique to detect and classify the paddy diseases and pests more accurately and less time processing. To accomplish this study, 3355 images comprises of 4 classes paddy images which are healthy, brown spot, leaf blast, and hispa was used. Then the proposed five layers of CNN technique is used to classify the images. The result shows that the proposed CNN technique is outperform and achieved the accuracy rate up to 93% as compared to other state-of-art comparative models.**

Keywords—Convolutional neural network; image classification; paddy classification; paddy disease and pest

I. Introduction

Plants disease detection is one of the major problems in sustainable agriculture [1]. Recent research outputs gives a strong indication towards the plants diseases that can occur in different stages with different rates [2]. The fact that plant diseases can also be transferred globally, makes it more complicated situation than ever before. It causes new types of diseases occur in places where they completely unidentified so that there is no local and fast solution [3]. Unexperienced farmers and manually finding solutions in paddy fields can cause the poor growth ratio and surely less ability for fight back with such diseases. In such cases, in time and accurate disease diagnoses are most important pillars of advanced agriculture [4]. It is very important to reduce unnecessary finance and wastage of other resources, thus obtaining high production of paddy with less risks. Advances in technology and computer vision application gives a better opportunity to improve and enhance the paddy field protection while extending the applications of computer vision in agriculture.

With a very high demand on productivity and the best quality of food, research in agriculture especially for paddy production is growing nowadays. Rice which is produced from paddy is the staple food for more than 3.5 billion people of the world's population including Malaysia [5]. For that, the needs of accurate diagnosis and fast solution to handle paddy problems have become the vital components in crop management. Diagnosis of paddy disease is a very challenging task to be performed manually due to several factors such as large size of paddy fields, various types of diseases, and non-native diseases which caused from environment, nutrient and organism [6][7]. There are several types of paddy disease such as leaf blast [6][7][8], brown spot [6][7][8], bacterial blight [7] and sheath blight [8]. Most of the paddy diseases can be identified based on colored spots or a stripe where each disease has it owns different color, shape, size and pattern. These signs of diseases can be found on paddy leaves or stem. In addition, different parts of paddy plant are also affected by the many diseases and parasites during several phases of growth [8].

Due to this complexity, identifying paddy diseases/pest manually is high cost procedure which leads to poor classification and time consuming especially when the farmers have lack of experience and knowledge to handle it. These can cause the diseases or the problems spread over and lead to greater losses of production. With the advance technology of image processing and machine learning, the problems in handling paddy problems manually can be solved in more accurate result, short period of processing time and require less human effort and expert.

For that, various types of image processing and machine learning techniques have been proposed by previous researchers to detect and classify paddy disease through affected paddy leaf [9][10][11][12]. Some of the classification techniques used are Self Organizing Map (SOM) neural network [6], Gaussian Naïve Bayes [7], Support Vector Machine [8], Radial Basis Function Network [9], Optimized Deep Neural Network with Jaya Optimization Algorithm [10] and the recent technique is Convolutional Neural Network (CNN) [11][12]. Convolutional Neural Network is one of the deep learning techniques that have exposed great promise result in image classification. This is due to the ability of CNN to provide end-to-end learning and to work on raw image without requiring a prior knowledge which can reduce the loss of information. However, in [11] CNN was utilized only as feature extractor where the last layer of CNN was eliminated. The extracted features from previous CNN layers were then fed to SVM to classify the dataset. While, in [12] a different dataset with different types of disease was studied. In this study, the CNN classifier will be fully utilized to classify the paddy disease to healthy or non-healthy. For that, in this study, a dataset consist of three types of paddy disease/pest images which are Brown Spot, Leaf Blast and Hispa is utilized. The augmentation process is then applied to the dataset to reduce overfitting problem. The proposed CNN classifier is then applied to classify the dataset. Finally, the performance of the proposed technique is compared with others classifiers which are ANN and MLP based on the classification accuracy.

The organization of the rest paper is as follows: the related work of paddy disease classification technique is given in Section 2. Section 3 presents the core of CNN and its fundamental architecture, while Section 4 describes the details of the research methodology and the proposed technique. A discussion of the result is presented in Section 5 followed by the conclusion in Section 6.

II. Related Work

In literature, many methods and techniques have been applied to identify the paddy diseases based on its images. The high ratio of these techniques are using generalize image processing techniques [34], Self-Organizing Map (SOM) neural network [6], Gaussian Naïve Bayes [7], Support Vector Machine (SVM) [8], Radial Basis Function Network [9], Deep Neural Network (DNN) based on Jaya Optimization (JO) Algorithm [10], and the recent technique is Convolutional Neural Network (CNN) [11][12].

In [6], the unsupervised SOM neural network is utilized to classify two major types of paddy diseases that are Leaf Blast and Brown Spots using image. Before the classification, the feature extraction process were done by detecting the infected part on the leaf image by using image growing and image segmentation techniques. The comparison is done based on four (4) different setting on the spots which are RGB, Fourier Transform, Arbitrary rotation of 50% spot with Fourier Transform of the 50% rotating spots. The outcomes of this work shows that the highest accuracy of 92% is obtained from Case 1 using RGB of the spot, which concludes that in the frequency domain, image transformation does not give better classification output as compared to original image. Islam *et. al* [7] used Gaussian Naïve Bayes to classify the paddy disease into three main categories including rice bacterial blight, rice blast and brown spot. The reason for choosing this classifier in their study is its simplicity with naive independence among the selected features. The RGB quantity values of the infected area is used as the input features. They claimed that this technique is more efficient as compared to the previous approach which generally applied on the calculated area of leaf. The classification accuracy achieved up to 90% shows that this technique able to produce a good result with fast processing time due to its simplicity nature.

Besides, in [8] the idea of using SVM for classifying three main paddy diseases including Brown Spot of Rice, Sheath Blight of Rice and Rice Blast, using paddy leaf images is presented. The images are segmented using Otsu's method in order to calculate the threshold value. They used the image processing technique from [32] for shape and color features are used in this study. Verma and Dubey [9] proposed Radial Basis Function Network and image processing to recognize five categories of paddy disease (leaf blast, brown **spot,** Sheath Blight, Panicle Blast and Stem Borer)along with non-infected images. The image processing is conducted for storage, transmission, and representation for machine learning in RBFN. The extracted wavelet features for Red, Blue and Green components of the images are applied in their study. The classification accuracy produced is over 95% for both training and testing datasets.

Instead of these classical classifiers, researchers nowadays are working on deep learning techniques especially for image processing problems. This is due to the ability of this technique to extract complicated information from the raw images. In paddy disease detection, deep learning techniques have been applied in [10] [11] [12]. In [6], Optimized Deep Neural Network with Jaya Algorithm was proposed to recognize and classify paddy leaf diseases. The images were captured directly from paddy field contain normal and disease leaf like bacterial blight, brown spot, sheath rot, and blast diseases. Six features include mean values and standard deviation (from color features), homogeneity, contrast, correlation and energy (from textures features) are extracted. In overall, the results show that their proposed approach outperform 98% as compared to the other comparative techniques which are the standard DNN, DAE and ANN classifiers. Shiravastava et al. [11] applied CNN classifier where pre-trained deep CNN model based on AlexNet for feature extraction and a multi Support Vector Machine (SVM) as a base classifier. Four types of disease were studied which are Rice Blast, Sheath Blight, Healthy Leaves and Bacterial Leaf Blight. The comparison has been performed with three different training and testing ratio including 80:2, 70:30 and 60:40. The accuracy of 91% has been gained with 80:20 of training and testing ratio.

Another work done in [12] proposed a hybrid technique of CNN with SVM. The drawback of CNN which contains maximum trainable parameters is improved by integrating SVM as classifier to remove this barrier and offer better classification accuracy to extract one dimensional feature vector. Nine common types of disease which are Rice Blast, Brown spot, Bacterial Leaf Blight, False Smut, Red Stripe, Leaf Smut, Leaf Scald, Tungro and Sheath Blight, considered in their work. The proposed technique successfully classified the nine paddy diseases and achieved more than 97% accuracy rate. Study by Atole and Park [13] also used a pre-trained weights and biases based CNN with AlexNet architecture for classifying paddy plants images. They performed multiclass classification based on three main classes called unhealthy, normal and golden apple snail infested.

III. Convolutional Neural Network

Convolutional Neural Network refers to a biological inspired ANN in which the information are transfer in uni-direction same as feed forward neural network. Its architecture is a motivation of visual cortex of brain that consists of simple and complex cells based alternating layers [14]. Generally CNN consists of convolutional and pooling layer or subsampling layers; however, it has many variants architectures that are grouped into different modules [15]. These modules are followed by conventional feedforward neural network based on a single or multiple fully connected layers. To form a deep CNN model architecture, the different modules are stacked on one another. A typical CNN based architecture for paddy leaves classification has been illustrated in Fig. 1. A paddy image has been given as input to the CNN architecture followed by different convolutional and pooling phases. The representation out from these phases has been feed into different connected layers and lastly the final fully connected layer presents the output which is actually a predicted class label. Despite, this architecture is more famous in the literature studies, but still several changes has been found in the recent years based on the objective of enhancing image classification in term of accuracy and computation cost reduction [16][17][31]. In all of these architectures, the major components of CNN are convolutional layers, pooling layers and fully connected layers.

A. Convolutional Layer

The primary objective of convolutional layer is to extract features and it learns the informative feature representation from its input image. Inside the convolutional layer, the neurons are arranged according to feature maps.

In the feature map, every neuron has its own receptive field that are connected to the nearby neurons in preceding layer with a group of randomized weights, usually named as filter bank [18]. According to the learned weights, it convolves the input neurons in order to draw the next feature vector and finally the outputs are forwarded using a non-linear activation function. Typically, a single feature vector has a constraint that all the neurons have the same weights; however, within a same convolutional layer, different feature maps have different weight matrix so that some informative features can be extracted in different stages [19]. In this situation, the j^{th} output feature map Y can be calculated using Equation 1.

$$Y_j = f(w_j * x) \tag{1}$$

Where, x is the input image, W_j represents the j^{th} feature map for the convolutional filter. In this context, the * sign denotes the convolutional operator that is used to computer filter model product of an input image at each location. While f is the nonlinear activation function [20][33] that extract the nonlinear features.

B. Pooling Layer

The main aim of using pooling layer in CNN, is to minimize the spatial resolution of feature space in order to achieve the high spatial invariance for the input distortion [21]. In the typical CNN architecture, mean pooling aggregation layers are used to disseminate the average input values of an image to the next layer. However, in the most recent architectures [22][23], max pooling layers pass the maximum values to the proceeding layer. Formally, in max pooling, the highest values are selected from each receptive field such as Equation 2.

$$Y_{jik} = \max_{(p,q)\in R_{ik}} x_{jpq} \tag{2}$$

Where, Y_{jik} denotes the j^{th} feature map as an output of the pooling operation. x_{jpq} represents the elements at point (p, q) in the pooling R_{ik} that expresses the receptive field at location (i,k). The difference between average pooling and max pooling is given in Fig. 2.

C. Fully Connected Layer

In order to extract the high order abstract features map during propagating through the CNN, a few pooling and convolutional layers are stacked over one another. The fully connected layer, which follow these layers aimed to translate the output of these layers and compute the high-level reasoning function [24][25]. In case of solving classification problems using deep CNN, the use of Softmax operator is more effective [26], while replacing it support vector machine (SVM) also leading to improved accuracy results [27]. Moreover, the computational cost of fully connected layer is always being challenged due to its compute-to-date ratio, which can be solve using global averaged pooling layer. Notwithstanding these contributions, the performance of different CNN based architectures can be still improve and thus needs further attention from machine learning researchers to investigate the issue associated with standard CNN and provide some research directions.

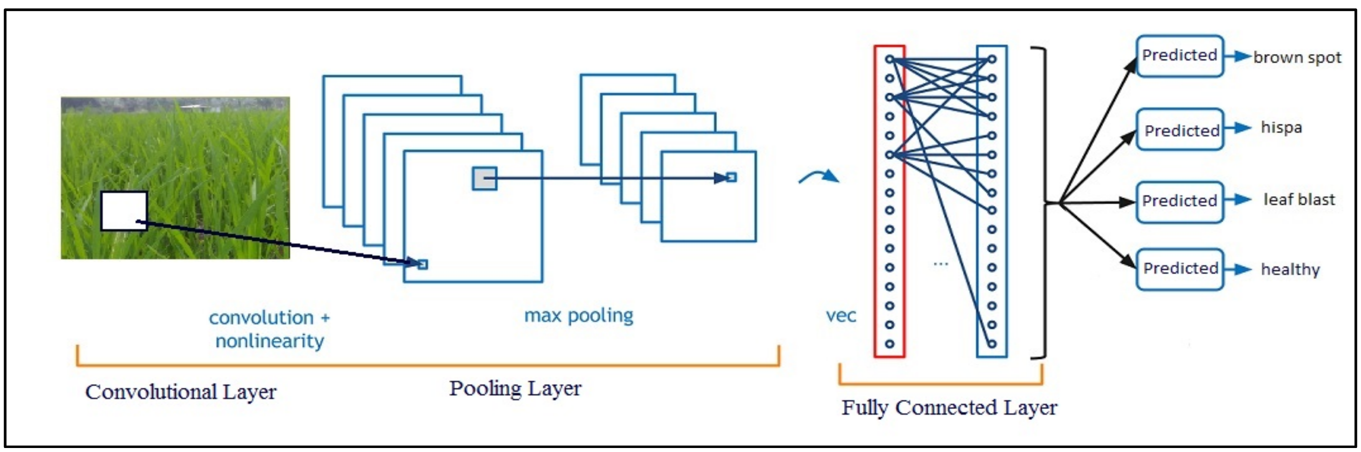

Fig. 1. A Standard CNN Model for Paddy Leaves Classification.

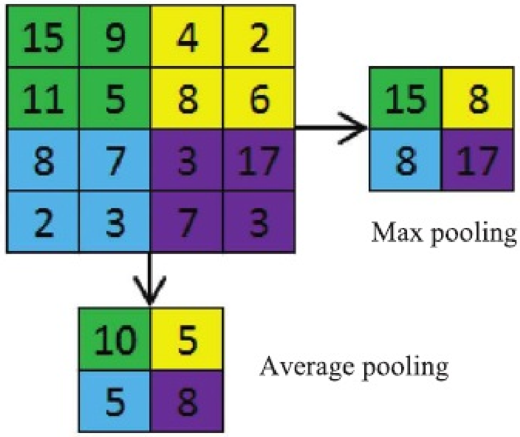

Fig. 2. Difference between Average Pooling and Max Pooling.

IV. Proposed Methodology

This section describes the whole procedure of CNN based model for paddy disease detection and classification. The entire implementation process has been divided into several necessary stages. Each of the subsections is discussed with process detail in the proceeding sections starting from dataset towards final classification.

A. Datasets Specification

The data for this research activity is collected from Kaggle repository [30]. Recently Kaggle is found to the most famous bench mark and real dataset provider for machine learning and artificial intelligence. This dataset consists of three major classes of paddy leaf images with disease which are brown spot, hispa and leaf blast and one class of healthy images. There is total number of 3355 paddy images. In these images, 523 were found for brown spot diseases images, 565 for hispa pests and 779 images for leaf blast disease. The rest of 1488 images are belongs to healthy paddy. In this research work, we have conducted the experiment with two different training and testing ratios that are 50:50 and 70:30. This split for testing and training ratio is based on with randomly selected images for both.

B. Data Augmentation

The main objective of applying augmentation process in this research refers to the increment in dataset elements and adding a minor distortion to the images in dataset. This augmentation helps to reduce the model overfitting during learning stage. In the field of statistics, artificial intelligence and machine learning, overfitting caused when the statistical model produces random noise and error rather than primary relationship. A few transformation techniques are included in data augmentation such as affine transformation and perspective transformation. The purpose of affine transformation is applied for linear transformation and vector rotation. The process of transformation is carried out using an application developed in C++ based on OpenCV [28].

C. Model Training

The proposed convolutional model is trained the dataset mentioned in sub-section IV (A) for paddy image classification task. In literature, there are many famous state-of-the-art frameworks for implementing CNN based models. The final architecture of the proposed CNN based model is given in Fig. 3. Normalized paddy images are the inputs of the CNN with a unite variance and a zero mean. In the proposed model architecture, convolutional layer based on a kernel size of 7x7 pixels is considered as a first layer with 16 output channels. Max pooling is considered as the second layer proceeding to the first convolutional layer, with kernel size of 3x3 pixels. The following all three layers are considered as fully connected layers consists of 100-50-10 neuron for each layer.

In the proposed CNN model, we have used only one convolutional and one pooling layer. As there are paddy images, which consist of only single texture and color patches, therefore there is no clear high level or large scale feature for the convolutional layer to learn multi-color or multi-texture images. In our research work, a single layered convolutional layer performs comparatively same as multi-convolutional layered architecture because of normal paddy images. The proposed simple architecture model also reduces the number of parameter for learning, with dramatically improve the network and avoid over fitting during learning phase. We also used the batch normalization approach during training phase in order to boost the training with fast convergence.

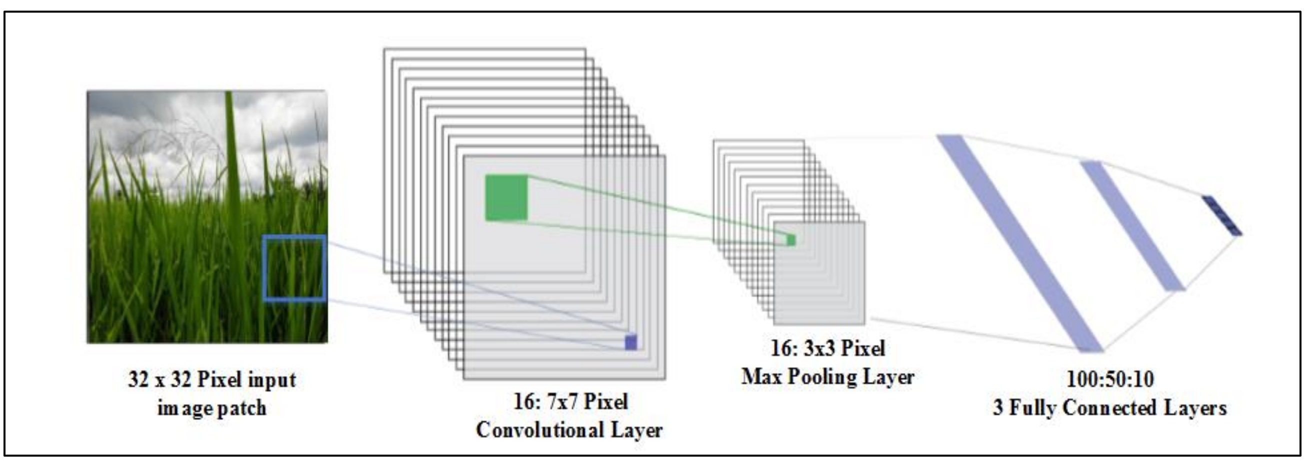

Fig. 3. The Proposed CNN Architecture for Paddy Disease Classification.

D. Experimental Setup

To conduct fair experiments for the evaluation of the proposed CNN model, we have used same hardware and software setup for all comparative models as well. Algorithms and approaches which have many inputs and update parameters are highly depending on parameters tuning. Parameter setting is generally a high computationally intensive task because some parameters have a large set of values to be evaluated. This section explains the experimental evaluation based on the feature learning ability of the proposed and comparative models, towards better solution for paddy diseases classification problems. All the experiments were conducted on Intel core i7 CPU, with 8GB of RAM having windows 10 operating system. The Python2.7 is used as compiler and language used for developing and testing these algorithms. For fair and fast implementation of the proposed and comparative approaches, an efficient numeric computational open source library Tensorflow [29] is used which allows a simple and fast development for both CPU and GPU support.

V. Results and Discussion

This sections gives a detailed view of the obtain results for paddy disease classification. The output of the proposed CNN model training process is based on all images in dataset containing original and augmented images because, it is well-known that CNN learn feature more efficiently on large scale datasets. Proceeding to the fine tuning of the parameters for the proposed CNN architecture, the high accuracy of 93.6% was achieved based on the 100 training epochs, which was 90.2% without fine-tuning. Furthermore, the trained CNN model was also applied to separate classes for individual testing. All the images from validation set has been tested for evaluating the performance of the proposed CNN based model for paddy classification. The results illustrated in Fig. 4, 5, 6, and 7 are focus on the number of total images for each class that are correctly classified by the proposed and comparative models. These results are the output of the proposed CNN trained model, and it is obvious from these results that the classes with less number of images in dataset got less accuracy as compared to the classes with high number of image in dataset.

In more detailed research activities, it is important to evaluate the proposed model based on comparison with a few well-known models for a clear comparative analysis. Although this dataset has never been used by any researchers in machine learning application specifically for paddy leaves images classification and disease prediction, it is impossible to compare it with any other example based on the scientific research literature. To cover the comparative analysis of our proposed CNN model, we have tested a few standard approaches including conventional artificial neural network (ANN), standard multi-layered perceptron (MLP) and a standard Support vector machine (SVM). The final results presented in different tables and figures reveals that the developed CNN model has performed better than the considered comparative approaches.

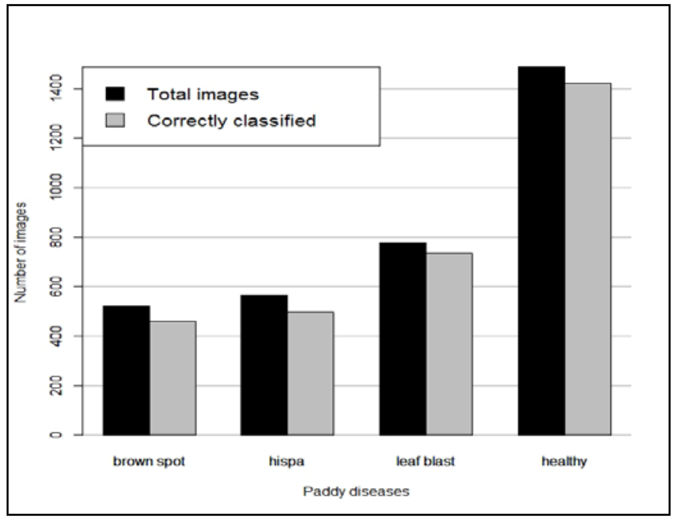

Fig. 4. Correctly Classified of Paddy Disease Images by the Standard ANN.

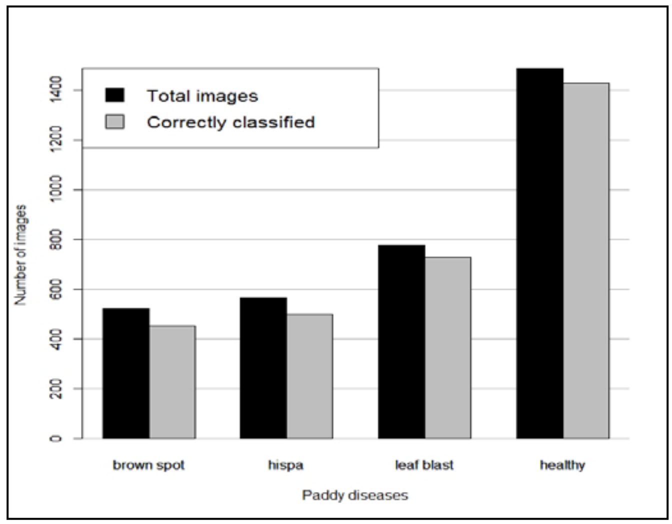

Fig. 5. Correctly Classified of Paddy Disease Images by MLP.

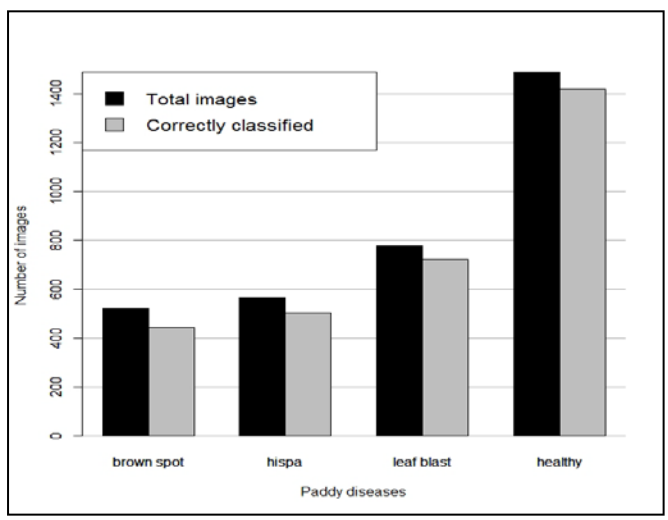

Fig. 6. Correctly Classified of Paddy Disease Images by standard SVM.

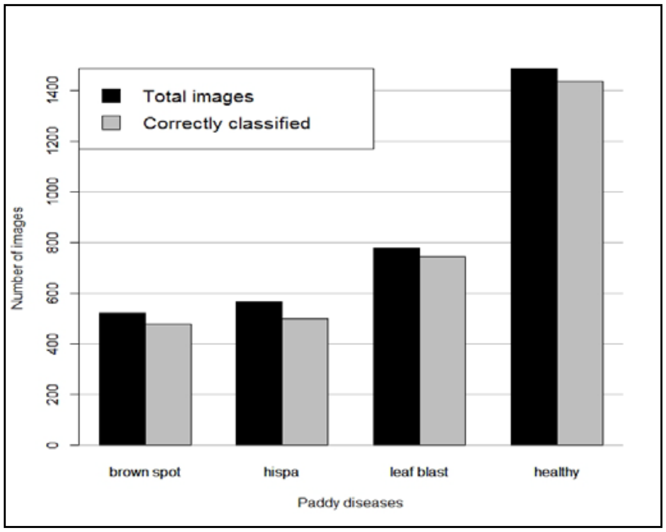

Fig. 7. Correctly Classified of Paddy Disease Images by the Proposed CNN.

All the comparative results for the proposed and comparative models have been presented in Table I for training accuracy and Table II for testing accuracy respectively. The accuracy has been calculated using standard equation presented in Equation 3. Final accuracy is the mean of each class accuracy.

$$Accuracy = {}^{t}/_{n}\,(100) \tag{3}$$

Where *t* is the number of correct classification and *n* is the total number of samples.

TABLE I. TRAINING ACCURACY OF THE PROPOSED AND COMPARATIVE MODEL

Techniques	Training & Testing Ratio	
	50:50	**70:30**
ANN	81.89 %	86.80 %
MLP	79.58 %	86.12 %
SVM	77.95 %	86.35 %
Proposed CNN	**87.30 %**	**93.60 %**

TABLE II. TESTING ACCURACY OF THE PROPOSED AND COMPARATIVE MODEL

Techniques	Training & Testing Ratio	
	50:50	**70:30**
ANN	77.89 %	82.60 %
MLP	72.58 %	81.12 %
SVM	71.80 %	81.45 %
Proposed CNN	**90.30 %**	**96.60 %**

VI. CONCLUSION

The recent research finds many methods and approaches for solving the plants classification and disease detection based on their leaves and other parts images. In all these previously proposed approaches, there is a lack of paddy disease detection and classification based on it leaves images using the most powerful image classification approach called CNN. In this research work, we proposed five layered CNN, with one convolution, one pooling and three fully connected layers that efficiently solves the problem of paddy disease detection and classification based on it images. The proposed model was able to give 93% accurately detected results for effected and healthy paddy leafs that helps in the automated paddy classification applications. This paper also conducted class wise detection accuracies for the proposed approach with a complete procedure of paddy disease classification from dataset specification towards final testing. The results presents in different figures and tables reveals that the proposed CNN model outperformed the well-known classification approaches such as ANN, MLP and SVM in paddy leaf disease detection and classification. In future work, we are planning to use entropy and information gain parameters for learning high order informative features from paddy images.

ACKNOWLEDGMENT

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Enhancement of Two-Tier ATM Security Mechanism: Towards Providing a Real-Time Solution for Network Issues

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***Abstract*—In the current scenario, the crime rate has tremendously increased with respect to the Automatic Teller Machine (ATM). During the last few years, criminals are becoming more sophisticated and paid more attention to ATMs. The majority of ATMs in India are working on a single authentication technique. The attacks, such as skimming, shimming, card cloning, card swapping, shoulder surfing, etc. works due to the use of minimal authentication in ATMs. So, the concern about the security of ATMs is reached to its peak level. Nowadays, banks have moved towards the two-tier authentication level. Recently in India, some banks have adopted the One Time Password (OTP) mechanism along with a UID number to perform the transaction in ATMs. In such a case, dependency on the cellular network for OTP is also a significant concern. To overcome these types of issues researcher proposed a two-tier authentication mechanism. The paper addresses the recent problems and their solution with the help of a two-way authentication method. To resolve the network issue, the researcher also proposed a novel technique, i.e., Security Question-based verification mechanism.**

Keywords—ATM-fraud; security: Unique Identifier (UID); shoulder surfing; shimming; trapping

I. Introduction

In this digital world, information and computer technology has built up its approach in almost every aspect of life. We are observing that the world is witnessing tremendous growth in the use of the internet, online transactions, data transfer, and information technology tools. Nowadays, the prime user of online transactions and the internet are banking and insurance sectors as well as financial organizations. They use this technology for making payments, transferring cash, and some additional services related to remittance. But recently, cybercrime is becoming a big issue. News headlines always frightening us about the fraud cases related to cash withdrawals, debit/credit card scams, information breach, and data theft, etc. These have a noticeable relation with the electronic system as well as the banking system. We know that maximum data and information are being online, and there is a massive chance that this information being attacked by cybercriminals. Cyber fraud has become so prevalent in the banking system, and with this, it leads to an enormous loss of money every year [1].

In the current decades, debit card has made the most remarkable evolution in the retail industry and as well as in consumer banking. The debit cards have become one of the most favored noncash retail payment gadgets after their introduction in the late 1970s. It is apparent from last decades that the growth in both as in the number of the transaction, as well as value, is multiplying (i.e., approx. 15 percent annually) [2]. At present, the use of debit cards is dominant/ruling in almost everywhere. This technology also enhanced the dispensation of cash via Automatic Teller Machines (ATMs) in order to avoid bank cash counter withdrawals. This card provides authentication of the customer on their account more effectively and securely as compared to their alternatives like cheques and passbooks [3].

As we know, on in one hand, the use of debit cards is continuously increasing, and on the other side, cardholders are facing high- profile security breaches [4]. To resist security breaches and plastic card fraud, the major payment card networks have generated their security programs such as Visa Card Information Program (CSIP), JCB Data Security Program, Master Card Site Data Protection (SDP), and American Express Data Security Operating Policy [3,4]. As these payment card network has built one more security layer on their cards to protect it from breaches and frauds. But on the other hand, attackers have found other techniques for fraud, such as skimming, Physical threats to ATM hardware, and ATM software threat.

For banking institutions, ATM Security has been consistently a significant issue because it is an inexhaustible resource of assets for attackers/cybercriminals. As we know, the problem related to the security of ATMs is becoming more acute. As any cybersecurity expert tries to patch one point but on the other hand, fraudsters find the others way because they are becoming more sophisticated in their techniques. So, security analysts have to protect the whole network rather than a single endpoint [5].

The paper proceeds as follows: related work about the topic is included in Section 2. Section 3 describes the development of plastic cards & their usage and different types of fraud techniques. Recent fraud in India is demonstrated in Section 4. The major finding is mentioned in Section 5. Section 6 includes a proposed security framework &

algorithms, along with the flowchart. At last, the paper is concluded with the conclusion and future work.

II. Related Work

In the current scenario, the research in the area of the secure transaction is going worldwide.

Adrian Fernandes (2020) has proposed an ATM that is based on biometrics. In the proposed work researcher uses biometric technology for the authentication of the account holder in place of the traditional authentication process, i.e., PIN. To perform transaction user is verified through biometric (i.e., fingerprint). The captured biometric is verified with stored biometric in the Aadhar server and after successful authentication transaction is performed. Besides, the researcher suggests that such systems must be constructed to protect the financial institution as well as customers from frauds [6].

B. Saranraj et al. (2020) have proposed a mechanism for the enhancement of ATM security by using Arduino. In the proposed methodology, researchers used two processes, i.e., Arduino Nano along with fingerprint and OTP mechanism. Users can perform transactions either by entering OTP (in the absence of original account holder) or through biometrics (in the presence of original account holder). In addition, researchers have mentioned that it will increase security by placing a two-way authentication mechanism and provides high proficiency as well as maintains a strategic distance from the illicit exchanges [7].

Ogata Hisao et al. (2019) have proposed an ATM security framework focused on avoiding jackpotting with the help of peripheral equipment. In the proposed work, the dispenser validates the reliability of the command obtained from PC for distribution of cash through ATM. In addition, all the transaction facts are recorded via a card reader. This framework fulfills three conditions and is based on the protection of peripheral equipment, and it can act as a safeguard if the PC is conciliated [8].

S. Shuka et al. (2018) have proposed an ATM security mechanism where they use a random keyboard and face resignation system for the authentication of users. In the proposed method, for making any transaction, the user has to go through a two-way security procedure. When a user goes for the transaction, a new page appears in the form of the random keyboard on the screen if the user is already registered if not then a link is provided on that page for the registration. The layout of the random keyboard is shuffled after every transaction. After that user has to enter the PIN for performing balance inquiry, withdrawal, and PIN change followed by facial recognition [9].

K. Sangeetha et al. (2018) have developed a security feature for the enhancement of ATM security by using RED-TACTON. RED-TACTON is a wireless network/human area networking technology that is consisting of transmitter and receiver sections. It has a fast data transfer rate of about 10 Mbps, and here data is transferred through the human body. In this procedure, initially, the user has to verify identity through a biometric, i.e., fingerprint scan if it matches then the PIN/password is transferred through RED-TACTON by touching the ATM to complete the transaction. They have also provided a way to perform the transaction with the help of others. In that case firstly, the other user passes the password through RED-TACTON after that the primary user will get an authentication message; if the primary user passes yes, then the transaction will take place [10].

K. T. Rayudu and M. Aravindan (2017) have proposed a security mechanism for enhancing the security of Automatic Teller Machines. Where they use One Time Password and Biometrics (i.e., finger vein biometric) with the help of Elliptic Curve Cryptography (EEC) technology to improve the surety of ATM. Elliptic Curve Cryptography is used to generate keys. Here they used a finger vein and RFID card to validate users after that; it will send a One Time Password (OTP) with the help of Bluetooth to complete the transaction [11].

Moses O. Onyesolu and Amara C. Okpala (2017) have proposed a security technique by using a Three-Tier Authentication mechanism for Automatic Teller Machine (ATM). Here they use three layers of authentication method; firstly, the user password followed by the biometric identification, and finally the user gets a One Time Password (OTP) on their mobile number (which is linked to their account number). In addition, they also introduced a new keyboard for the existing system with some unique character keys and alphabet keys. The authors also stated that all these authentication techniques must be in affirmative prior granting access to the user 12].

M. Dutta et al. (2017) have proposed a security procedure for the ATM transaction with the help of fingerprint recognition. In proposed work, they have used the fingerprint of the users as the password followed by traditional Personal Identification Number (PIN) in order to overcome the security issues in ATM money transactions. Here fingerprint module generates a four-digit code as a text message, which is sent to the registered mobile number. After the validation of the code, the user is allowed to complete the transaction [13].

N. Ahmad et al. (2016) have proposed an Advanced Encryption Standard (AES) card less Automatic Teller Machine biometric security system. The proposed security is developed by using a Field Programmable Gate Array (FPGA). The proposed system is consisting of the fingerprint scanner, multi touch screen display, RS-232, FPGA DE2-115 board with cyclone IV, and PS/2 keyboard. Here in the proposed system user has to enter identification number followed by the biometric scan, i.e., fingerprint as an input to the ATM. Advanced Encryption Standard (AES) is used to encrypt the identification number as well as a fingerprint scan. After that, the encrypted information is sent to DE2-115 and matched with the stored data for authentication [14].

Amala et al. (2016) have proposed a modified biometric authentication technique, where they used a modified Radial Basis Function Network (RBFN) to discriminate between face patterns and non-face patterns. In addition, they reduced the complexity of the RBFN with the help of Principal Component Analysis (PCA). PCA to obtain the Eigen Vector; the RBFN network takes these vectors as input for training and reorganization [15].

III. Background

John Shephard-Barron was invented ATM (Automatic Teller Machine) in 1960, and it is a computerized telecommunication device. It starts its functioning by inserting a plastic card, i.e., a credit/debit card. This card is encoded with the user's banking information on a magnetic stripe, i.e., Personal Identification Number (PIN) and account number etc. [16]. This device permits banking as well as financial institutions and their customers to gain access to their accounts by means of a secure method of communication. The main aim of ATM is to reduce the workload of the banking sector. This device acts as a self-service terminal, which provides facilities like a dispensation of cash as well as accepts cash [17].

During the transaction process, the ATM sends the information provided by the user to the banks' server, and after its verification, the user is allowed to complete the transaction. The cardholder (i.e., user) and the host processor (i.e., server) are communicating with each other with the help of a gateway (i.e., Internet Service Provider ISP). And then the whole transaction details are sent to the bank's server. The plastic card is secured with Personal Identification Number (i.e., PIN), which is encrypted with the help of some standard encryption technique. There is no technique or process to get a PIN from the plastic card. ATMs are of two types; the basic one is to dispense cash only on the other hand, the second one is more complicated, which accepts as well as dispense cash. It consists of two input devices (i.e., Card reader and keyboard) and four output devices (i.e., Display Screen, Receipt Printer, Cash Dispenser, and a Speaker) [18].

Nowadays, news headlines are always frightening about the frauds related to Automatic Teller Machines, and in the current era, it has become a hot button issue. The fraudsters have become more sophisticated in their method to find the loophole. So, security experts have to protect the whole network rather than a single point. Some common ATM security treats are:

- The most straightforward and preliminary ATM treat; Physical threat to ATM.
- A fraud technology used to capture the details of plastic cards and then transferred to the duplicate cards: Skimming.
- Threat to ATM Network Software.
- Jackpotting.
- Shimming.
- Card and Cash Trapping.
- Transaction Reversal.

Physical Attacks: In physical attacks, the attackers rob the ATM and take cash from the safe with the help of heavy tools like cutting torch or explosive. This type of attack is also comprising of solid and liquid explosives as well as the removal of ATM from its location, and then they use some methods to get access to the safe [19].

Skimming: In this process, the skimmers use a small skimming device that fits over the actual ATM card reader slot. When the user swipes their card from it, the data and information are captured from the card and stored on the device. In addition, the skimmers place an undetectable camera to record the PIN [19].

Threat to ATM network software: In this type of attack, security criminals breach the ATM network to get control over the ATM server, where they install malware with the help of improved code. With the help of this code, they gain access to the internal command of the ATM. And now, the ATM server will act like a Command & Control (C & C) server, which commands various infected endpoints to dispense cash [5].

Jackpotting: It is the technique through which cybercriminals manipulate hardware and software vulnerabilities in ATMs that result in spitting heaps of cash from the machine. ATM jackpotting was firstly spotted in the European country in 2016, and now it was continuously spreading throughout the world. In this technique, a tiny bore is made next to the keyboard through which a cable is inserted to connect the laptop. Once attackers access a certain port, they made complete control on the machine and instructed them to dish out the cash. With the help of this technique, attackers can dispense and clears all cash from ATMs in just a few minutes.

Shimming: It is similar to skimming, where the attackers use paper-thin in the card reader to steal data from chip-enabled cards [20].

Card Trapping: In this method, the attacker hacks the ATM by installing a gadget inside the card slot. In this process, they use the most common device (i.e., Razor-Edged spring), with the help of this, the attackers trap the card and stop it from ejecting. Besides that, the attacker acts as a fellow customer and memorize the PIN trough shoulder surfing or offers to help and suggests to re-enter PIN and complete the transaction again. Then all the thief needs to do once the victim has gone is to retrieve the card from the ATM [21].

Cash Trapping: It is one of the most prominent techniques in which attackers put a gadget (i.e., glue-trap) into the ATM physically to trap the cash. In addition, a bogus dispenser is allocated in the place of original, and on the other hand, the installed device traps the allocated cash [22].

Transaction Reversal: It is one most sophisticated technique used by cybercriminals to lift cash from ATMs, where they use stolen or skimmed cards to refrain from detection. Generally, ATM is jammed by the attackers by reversing the logic of the host application. This process requires a chain of sequences for fabricating promiscuous error codes, as well as the reversal of the unwanted transaction. This type of fraud is only exercisable to those ATMs that support Motorized plastic cards [23].

IV. Recent Frauds in India

On 9 December 2019, Kolkata police had cracked Kolkata ATM fraud case (skimming) of siphoning money from the account of around 71 users of ATM. The police claimed that they had arrested the accused Siliviu Florin Spiridon (28) precisely after 8 days from Greater Kailash Delhi. The accused had started withdrawing money from November-30 to December-3 using skimmed data from Kolkata. In addition, they said that the accused used to visit India 3 times this year via tourist visa firstly on 14 March, 19 July and 14 October. They have collected around 12 sunglasses, 24 caps, a huge collection of clothing, and costly mobile phones and skimming devices [24].

In May 2018, a 16-year-old girl named Nisha was cheated with Rs. 29,000 by two people on an ATM at Dwarka Sector 14, and after a day that girl was reportedly committed suicide. She had visited the ATM to withdraw some money for the medical treatment of her father, but due to lack of awareness she handovers her two debit cards to the person who was there at that time to withdraw the amount. During the process, they swiped the cards and made the fraud very smartly without letting her know, and a huge amount of money was falsely transferred. She hanged herself because she blamed herself for the loss of money [25].

In April 2018, a person JINTO JOY who runs a firm for the exchange of money at tourist spots of Varkala at Thiruvananthapuram. He uses a small hand-held device and a camera of the size and a small led bulb to steal the money from his client. He was arrested for reportedly siphoning money from a French man's (Francois Mousis) bank account by cloning his card, where he uses a camera to capture the password. In contrast, his staff uses a small skimming device to steal information on the card [26].

In April 2018, a doctor was arrested from a government institution for his involvement in skimming and ATM fraud. According to the report, firstly the doctor had made a firm and acquired five Point of Sale (POS) machines for the firm. The gang involves in the skimming and ATM fraud by using the POS machine for siphoning the money their client account. The money was deposited in the account of the doctor who takes more than 30% of the whole money, and the rest of the money was distributed among the gang member [27].

On 9 September 2017, a man named Darshan Patil has swiped his card for a toll tax of Rs. 230 at Khalapur toll plaza around 6:27 pm. By 8:34 pm, a total of 87000 have been drawn from his account. As per the record (reported at Hadapsar Police Station Pune), he doesn't receive any OTP for the transactions. Cybercriminals have performed more than 5 transactions for siphoning the amount from Patil's account. One of the security experts have explained during the swapping process; we give our card to another person for the transaction. During this process, our card is until in machine until the bill came out from the machine, and it provides enough time for a cyber-criminal to steal data from card [28].

V. Major Findings

1) Majority of ATM users does not follow the rules described by banks:

- Not more than one person in an ATM chamber for the transaction.
- A huge number of people performing transactions while using caps, sunglasses, and handkerchiefs on their faces, etc.
- Maximum numbers of ATM having no security guards to care of rules provided by the banks or to instruct the users.
- A considerable number of ATM having distorted gates, alarm systems, cash dispensers, keyboards and jammed keys etc.

2) All the points mentioned above will increase in the ATM fraud rate, i.e., by shoulder surfing, card cloning, password stealing, keyboard-jamming, and card/cash trapping etc.

3) Many ATMs have equipped with finger printer sensors and voice recognition systems; even after having such features, they are working on a single level authentication factor.

4) Recently, few banks implemented a 2FA (Two Factor Authentication) mechanism based on OTP to withdraw a certain amount. But they didn't provide any solution in case of network issues, device is lost or damaged, and any kind of accidental issues.

VI. Proposed Security Mechanism

Nowadays, there is a tremendous increase in numbers of ATM users due to the advancement in digitalization. As a result, the financial sector has moved from cash to cheque and currently towards the plastic cards [29, 30]. From the last decade, plastic cards emerged as a widely accepted mode of transactions across the world [31].

According to the times of India, there is around 9% growth in fraud rate on ATM from the year 2017-18 to 2018-2019 and causes a loss of about 21.4 crores. In addition, there is a rise in the ATM fraud case, but due to improvement in security features of ATMs or plastic cards (i.e., chip-enabled mechanism) the country has witnessed a huge decline in terms of money loss, i.e., around 305% from the last year [32].

The ease and convenience of ATM have made the financial users rely and trust on it. But at the same time news headlines are threatening about the frauds related to ATM, i.e., skimming, shoulder surfing, card swapping, and password-stealing etc. To avoid all these bluff techniques, researchers have proposed a two-tier security model. Recently some banks in India are using the OTP feature to avail cash, but they did not provide any solution in case of any failure in a particular network or any accidental issue (i.e., cell phone damage and stolen etc.), which lead to transaction failure. In the proposed framework, there is an alternative feature to avoid these types of issues by choosing the random security question from the database. The details of the framework are elaborated in the subsequent sections.

A. Working Procedure of Proposed Security Mechanism

Firstly, the bank's personnel collect the client's information, i.e., name, aadhar and e-mail, etc. In addition, they collect an activated mobile number and at least four security questions as well as their answers. After collecting all the information from the customer, a unique database for bank clients is prepared with a unique ID. The registration process and the creation of the client's database are shown in "Fig. 1".

The proposed framework is divided into two phases. In the first phase, the authentication process is done. Whenever the bank's client needs to perform a transaction firstly, the client has to insert the card and enter the unique UID/PIN provided by the bank after that client has to select the desired transaction process. The outline of the process is mentioned in "Fig. 2".

In the second phase (i.e., verification phase), there are two ways to complete the transaction process. Firstly, with the help of OTP or in case there is accidental or some natural issues with the network or device, then the client can use an alternative method to perform a transaction (i.e., security questions). To complete the transaction process client has to authenticate with either OTP or Security Question. If the client wants to perform the transaction with the help of mobile. He/she has to select the authentication process with the mobile option, and an OTP is sent to the registered mobile. After that, a time slot of 90 seconds, as well as a counter of two attempts, is assigned in which the client has to enter the correct OTP. In addition, if the client fails to enter correct OTP in all attempts within the given time and counter, the card has been blocked for 24 hours or the client has to contact with either bank or customer care. The outline of the process is mentioned in "Fig. 3".

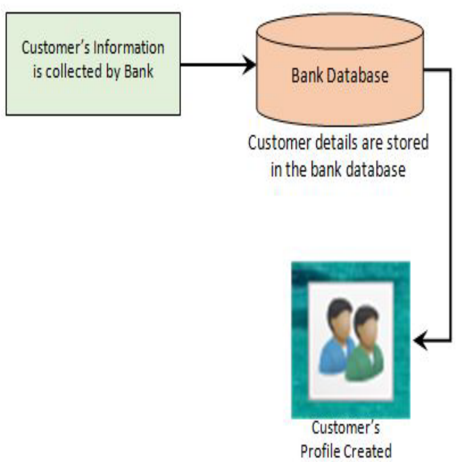

Fig. 1. Registration Process of Bank's Client.

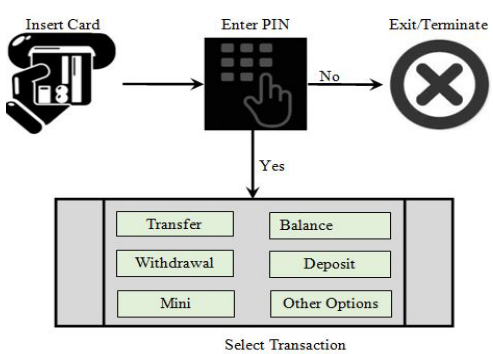

Fig. 2. First Level Authentication Process for Transaction.

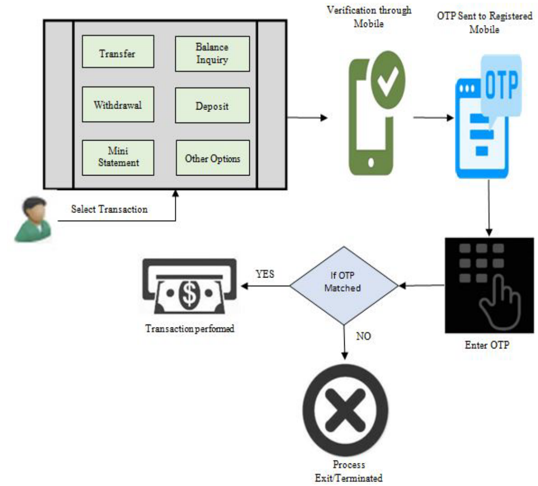

Fig. 3. Authentication Process (Via Mobile) for Transaction.

In the phase second (i.e., verification phase), if the client wants to perform the transaction with the help of a security question, then the client has to go with the security question option. A security question will be displayed on the screen from the client's database. The client has to answer the security question correctly in allotter time as well as in allotted counter to perform the transaction.

Once the security question displays it is stored in the database, either the client answers it correctly or not, it will not display in the next transaction. We have done this to avoid shoulder surfing, card swapping, cloning etc. For the security perspective, researchers have set a timer as well as in the number of attempts to answer the security question. If the client fails to enter the correct answer in all attempts within the given time and counter, the card has been blocked for 24 hours or the client has to contact with either bank or customer care. The outline of the process is mentioned in "Fig. 4".

B. Proposed Flowchart

The complete flow diagram of the proposed ATM security mechanism is outlined in "Fig. 5".

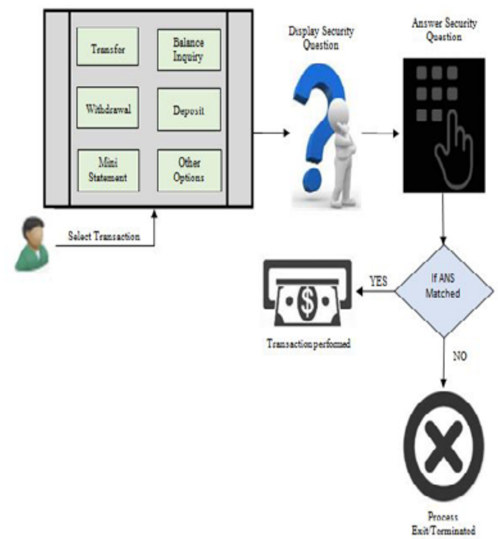

Fig. 4. Authentication Process (Via Security Question) for Transaction.

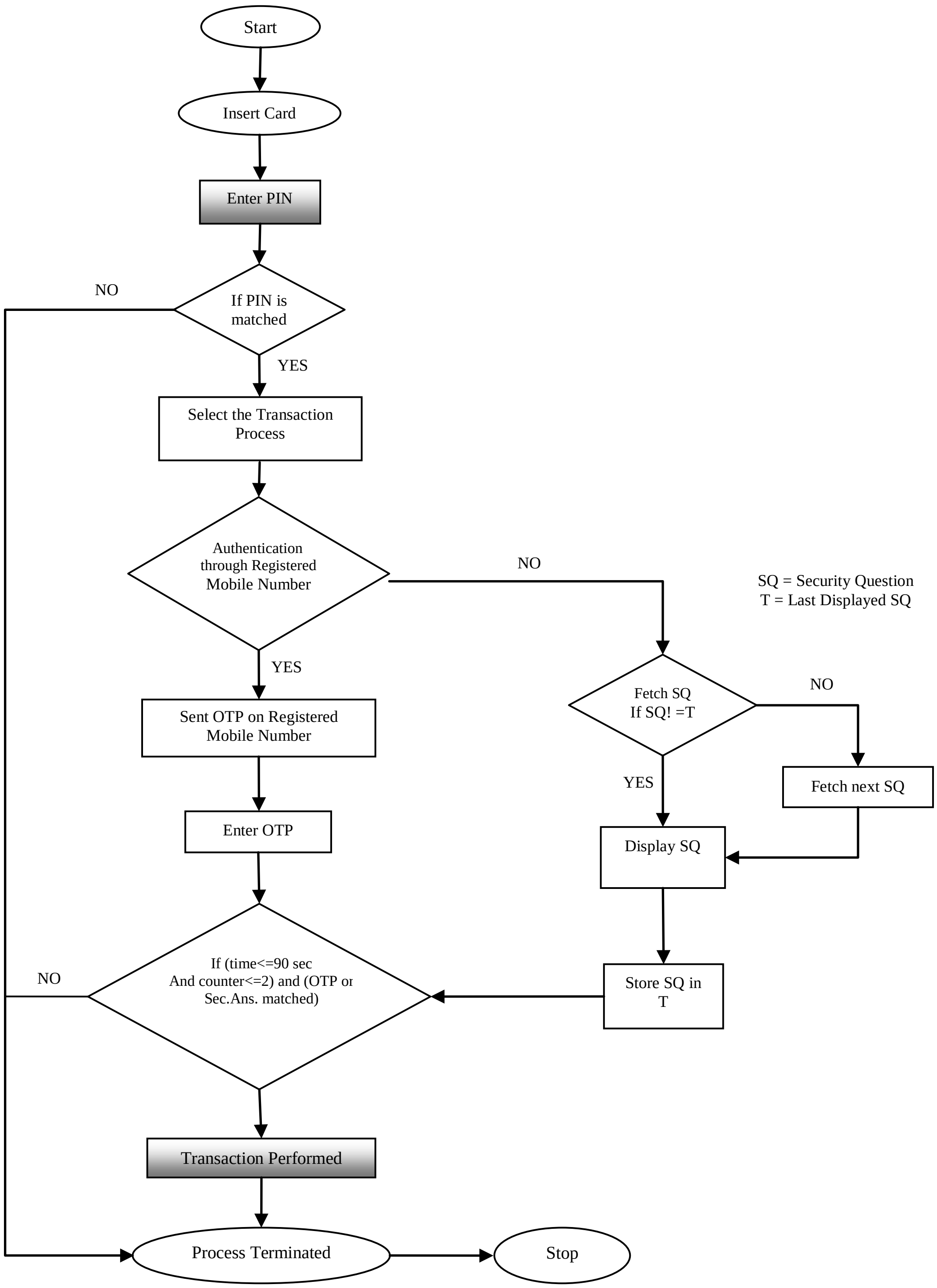

Fig. 5. Flowchart for the Proposed ATM Security Mechanism.

C. Proposed Algorithm

1. Start
2. Enter “Uid” and store in UID
3. If UID is not matched, then Go to step 22 else Go to step 4
4. Select Process
    - Withdraw
    - Mini statement
    - Pin Change
    - Etc.
5. Enter Y or N as the choice to authenticate by mobile.
6. If choice == Y then Go to step 7 else Go to step 12
7. Set the counter C=1.
8. Send OTP to the registered mobile number.
9. Start the timer for 90 seconds and repeat steps 10 to 12. If Time Elapsed, Go to step 21
10. Enter OTP
11. If OTP is matched then complete the TRANSACTION and Go to step 22

    Else if C<3, then set C=C+1. Go to step 8 for the regeneration of OTP else Call Card Block Procedure Go to 22
12. Set counter=1
13. Start Timer of 90 second
14. Repeat steps 15 to 20 till Time is not Elapsed and Counter! =3 else Call Card Block Procedure Go to 22
15. Fetch security question SQ from the database
16. If SQ! = T, then display it
17. Else fetch the next question from the database and display it
18. Enter “Enter Security Answer”
19. Save the question number in T
20. If the answer is wrong, then go to step 21 else complete the transaction
21. Process Terminate
22. Process End

VII. Conclusion and Future Scope

Due to the advancement of technology, the dependency on ATM is continuously increasing, and the banking sector is consistently encountering the risk of privacy and security. The number of cases regarding misuse of plastic cards is endlessly growing, and the security procedures applied by banks are not optimal. From the literature survey, it is revealed that the maximum number of ATM fraud/attacks is occurring at its authentication phase. Many banks have started a two-tier authentication process with the help of OTP. Still, there is an issue; if a client forgets to carry its mobile or if there is any network issue (i.e., network failure, network ban due to some circumstances) then the transaction process will become incomplete.

To avoid all these issues, researchers have presented two-tier security architecture to remove network dependencies. In the proposed framework, there is an alternative feature to avoid these types of issues by choosing the random security question from the database. Before the user is granted access to the transaction, these two authentication methods (a combination of any two, i.e., Personal Identification Number along with One Time Password or Personal Identification Number along with Random Security Question) must be affirmative. In addition, with the adaptation of this security framework, the problem of identity theft, shoulder surfing, card cloning, password stealing and illegal withdrawal of cash will be eliminated. The siphoning of this framework to the financial sector would improve the security of the ATM system and also restore the customer's trust. Future Work: The researcher is planning to further extend the work as well as testing and building a financial machine (ATM), having additional features for serving every kind of disabled person.

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A Novel Pre-Class Learning Content Approach for the Implementation of Flipped Classrooms

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***Abstract*—The nascent recognition of computing in curriculum across countries is also accompanied by several pedagogic inefficiencies especially concerning insufficient time available for teacher-student interaction. In this paper, a flipped classroom concept was identified as an effective approach to teaching students at various levels in the academia including Higher Education. Preparing the pre-class content and considering the format used to deliver it has not gained much consideration. There are several ways in which this content could be provided to students to prepare them before an in-class activity where a flipped-classroom approach can be implemented. The present study analyzed the success of the flipped classroom concept based on a comparative analysis of the two types of flipped classroom pre-class content delivery methods: online videos and online PowerPoint slides. Evaluation was performed using paired T-test. The results show that the two approaches have significantly different means and huge differences between them. The students preferred online videos to online PowerPoint (ppt) methods underlining the importance of the proposed flipped classroom approach.**

Keywords*—*Flipped classroom; active learning; online videos; student-centered approach; increased interaction; pre-class content

I. Introduction

In recent times, new approaches are being adopted to enhance students learning and better improve on the student-teacher class interaction. Amongst the several approaches used is the flipped-classroom method which has shown promising results [1, 2].

A. *Pedagogical Loopholes in Infusing Skill Development among Computer Science Students*

Students with a Higher Education degree are expected to be equipped with skills related to creativity, problem-solving, analytical skills, critical thinking, multi-tasking, and resilience. The student must learn to work independently as well as in groups. In this context, the education system poses certain inefficiencies concerning its effective transmission among students. Inefficiencies of institutions in the form of limited time to practice, as well as limited interaction with faculty prevails. Moreover, there exist poor learning methods for students, especially the use of the traditional methods of teaching, and in addition, insufficient teaching approaches [3, 4]. Low self-efficacy, lack of motivation to learn courses, and lack of factors which identify loopholes in the system to infuse skills among students [5].

B. *Importance of Interactive Classroom in Class Activities: Emphasis on Flipped Classroom Approach*

A flipped classroom concept represents a transition from a teacher-centered approach to a student-centered approach whereby students have access to theoretical content via online videos, presentations, learning management systems before attending the classroom session. This encourages students to build an understanding of the concept, take notes, prepare questions so that the classroom session is turned into a hub of learning and every student is engaged enthusiastically [6]. For teachers, the flipped classroom helps in using their time more effectively to help weaker students understand and implement the taught concepts better. Steps followed by instructors and students in a typical flipped classroom session are clearly shown in Fig. 1(a) and (b), respectively.

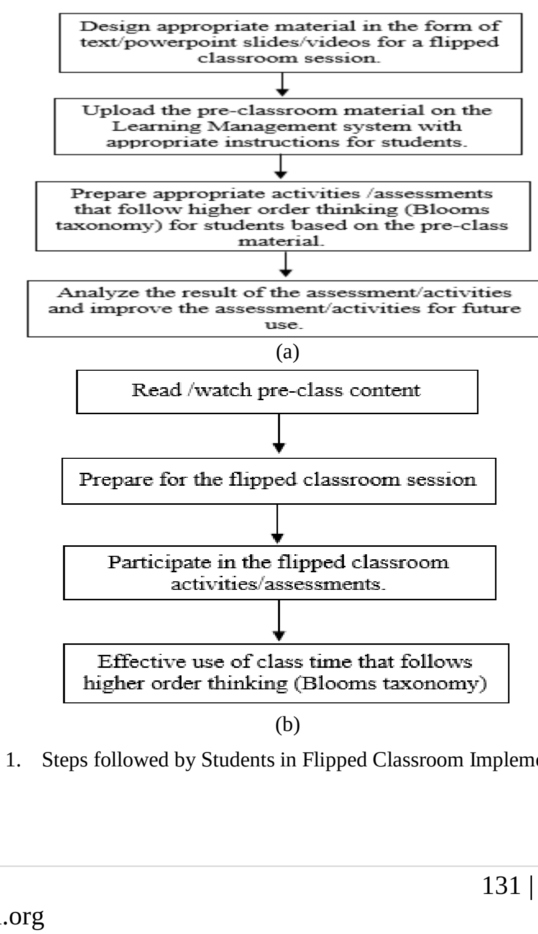

Fig. 1. Steps followed by Students in Flipped Classroom Implementation.

The interactive classroom approach using the flipped classroom method can be a useful approach in enhancing the teacher-student relationship [7]. A number of research papers have reported that the flipped classroom develops a positive attitude in students and gives a better performance in taught courses in comparison with the traditional classroom teaching approaches [8-10]. Though a lot of research have been done on how to develop effective in-class activities and focus on student-centered learning [11-13], not much has been done in considering the quality of out of class content provided to students.

A quantitative study conducted in [14] found that student achievement was higher in the case of a flipped-classroom approach in comparison with traditional approaches. Though in-class activities should focus on active learning both [15] and [16] found that a flipped classroom was more effective in teaching concepts and had a positive impact on learning and student motivation.

However, authors in [17] and [18] have found that there were very little or no significant results in replacing the traditional teaching approach with the flipped classroom approach applied in introductory biology and nursing studies. These contradicting results lead to the conclusion that flipped classroom can be an effective strategy in improving the learning behavior of students. Most of these studies also indicated that the benefits of implementing a flipped-classroom approach highly depends on the readiness or ability of students to work independently and acquire self-regulatory skills to come prepared for the out of class tasks [19].

Porcaro *et al.* [20] indicated that most of the students (89-93%) completed a pre-class tasks when the pre-class content was in the form of video lectures. This may indicate how well prepared the students were, and may also indicate the other factors such as how different format of the out of class content influences student's readiness in preparation for a flipped classroom session.

Most of the pre-class content is in the form of pre-recorded lectures or screencast [21]. Other methods of pre-class content dissemination include readable contents, Blogs, and Google Docs [22].

The subsequent sections of this paper are organized into the following sections: In Section II we discuss in detail the need for the study, while in Section III we present our proposed research methodology. In Section IV we give the results and findings, while in Section V we discuss the results. In Section VI the paper is concluded and therein we indicate opportunities for future research works.

II. Need for the Study

In light of the above-mentioned facts which include insufficient class time highlights the need for a technology-based interactive method such as flipped classroom sessions. These are constructed and organized by teachers in the form of videos, presentations or pdf reading material uploaded in various leaning management systems. It is thus crucial that teachers prepare the content carefully as it helps in building the students taking the course. It is a common phenomenon for teachers to take an active interactive session rather than a session executing an entire topic within a class session. Hence, it is necessary to investigate various methods for designing pre-class materials for successful flip classroom implementation. Besides, the tools used in the flipped classroom concepts are well prepared and understandable to the students [23]. The pre-class material design could be in the form of online PowerPoint (ppt) presentations, videos, learning management systems, etc. There is also the need to make a comparative analysis of the type of pre-class material that effectively helps the students.

We look at two formats in which pre-class content is made available to the students. First is reading text format or in the form of detailed ppt slides and video lectures.

A. Text Material

Textbook-style reading is usually used by lecturers to provide students with a short and straight to the point easy to understand low-level content in line with lower items in bloom's taxonomy. These are used at high school and university levels and are considered as an important element of the learning experience. When we compare textbook reading to video materials, we can state that it is easy to search and read through the relevant content multiple times with ease. A study in [24] showed that textbooks are often the main resource for the majority of the students. Though textbook reading materials are often used in traditional teaching style, when used in a flipped classroom environment, students are required to have read and understood the concepts to be able to apply it to the corresponding in-class activity. This is in contrast to a traditional teaching style where reading pre-class content is not enforced [25]. In a traditional teaching environment, many students do not bother to read the assignments [26, 27].

B. Video Lectures

Video lectures focus on two modes of information processing which are: visual and auditory. According to authors in [28] who used dual coding theory, the more sensory pathways that a student can use to interact with the material, the more likely the student will remember the content [29]. Yadav *et al.* [30] suggested that video may be a more powerful medium for cognitive and affective information processing compared to text reading alone.

In this paper, we used the two content learning strategies for out-of-classroom content learning in a flipped-classroom approach, while keeping the implementation of the in-class activities for future works.

- Central aim

The present study aims to analyze the role of flipped classroom concept and its tools implemented in higher education for developing skills among computer science students.

- Central question of the study

Is the benefit perceived by students in a flipped classroom approach based on the type of pre-class content design for a flip classroom approach?

Is there a difference in the performance of the students studying with the pre-class content materials (online videos, online power points slides) in the context of higher education?

III. Research Methodology

This sections describes the method, strategy and organized processes performed in collecting and analyzing the required data for achieving the aim of the research study and solving the central research problem [31, 32]. For the present study, authors have employed a positivist paradigm which is objective and predictable in its approach. Besides, a descriptive and explanatory research method has been applied for analyzing the characteristics of the selected research topics whereby these methods were used to collect quantitative data for the same. Another part of the research methodology is a suitable research approach that guides the course of study. Authors have used the deductive research approach here. With this approach, a structured theory is formed in the initial phase of the study which deals with quantitative data collection [33]. Hence the study involved two different pre-class flipped instruction methods, namely, online video lectures versus online lecture material (text or PowerPoint (ppt) slides), and the result of these methods were evaluated with the students preferences and other associated parameters concerning higher education.

A. Participants

A survey was administered to students. The survey was majorly administered among 160 students pursuing higher education. As for the respondent's profile, the major targeted population included students of computer science subjects in higher education. Also, the sampled population was obtained through the method of non-random convenience sampling method, i.e. the samples were selected as per the convenience of the researcher.

B. Measurement Instruments and Measures

The measuring instruments were survey questionnaires (close-ended and structured), which had a demographic and inferential part which helped in assessing the impact of flipped classroom sessions. For conducting the survey, prior permission was taken from authorities of the concerned institutes, faculty, and students. The inferential section comprised of scores of students undertaking flipped classroom material. Around 190 undergraduate students were approached as per the convenience of the authors in approaching them for the required survey and 160 of them reverted. Two different pre-class learning materials were used– online video lectures and online lecture material. The results of these methods were compared and evaluated based on student’s preferences and other associated parameters. The topics were from a problem solving subject taught to students in their first year of Computer Science. The topics were introductions to different sorting algorithms. In the case of video-based pre-class learning materials, a video was uploaded to explain to students the concept of selection sorting approach [34, 35]. In the case of reading material based flipped classrooms, the students were required to read and go through the PowerPoint slides to understand the algorithm for bubble sort.

C. Procedure of Data Analysis

Data was collected based on scores of students in common assessments with the pre-class content students used to understand and study the concept covered in a flipped classroom teaching. A t-test Statistical Package for Social Science (SPSS) v21 was used to evaluate the significance of the results.

The assessments were conducted in the class after a quick recap of what was covered in the pre-class material for both the types of material power point/text and video lecture. Assessments conducted were at the sample level of complexity. All questions were carefully drafted to avoid any type of bias. Questions ranged from multiple questions to problem-solving using the concepts learned. Scores obtained by the students in all three assessment were used to evaluate the differences between using two types of materials.

IV. Results and Findings

The results presented in Fig. 2 revealed that only 11.54% of the students were not aware of the flipped classroom sessions and preferred online lecture notes to online videos. Also out of the remaining students who knew about the concept, 59.62% of them preferred online videos to online lecture notes.

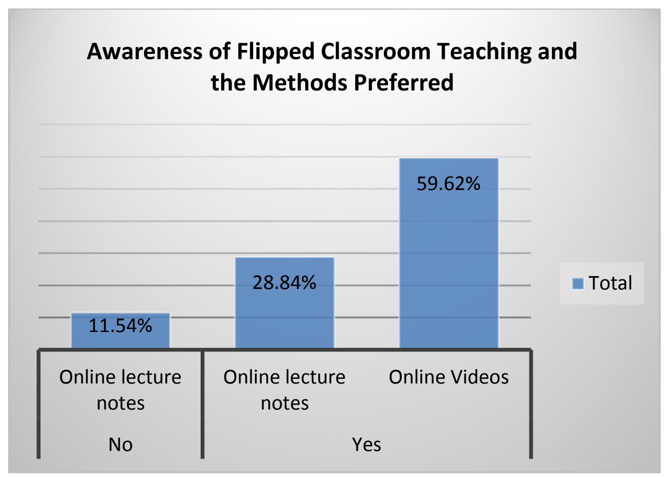

Fig. 2. Awareness of Flipped Classroom Teaching and the Methods Preferred.

Given the general and background information of the respondents, the next section took into account the inferential analysis including hypothesis testing for presented objective of the study thereby presenting several insights and implications of the same.

A. Inferential Analysis

To achieve the objective of study which aimed to provide a comparative analysis of the two types of pre-class content methods to support flipped-classroom approach: online videos and online lecture (reading) materials in the form of text or PowerPoint slides, the authors have used the t-Test Paired Two Sample for Mean difference determination. This method helps in making a comparison between two dissimilar approaches of measurement or two diverse treatments concerning a common subject [36]. In this section, a comparison was made between the two types of pre-class content design to support a flipped classroom concept. Furthermore, this method was used to test the means of a population between two groups such that the null hypothesis states that the means of two populations are equal. However, the variances of both populations are not necessarily equal.

Therefore:

$H_0$1 means there is no significant difference in the mean of the video preferring group and PowerPoint slides preferring group,

while H_A1 means there is significant difference in the mean of the video preferring group and PowerPoint slides preferring group.

Table I shows that the p-value is very close to zero and is thus less than 0.5. Therefore the null hypothesis is rejected. This means the mean of the two flipped classroom teaching methods are not the same. Also, P(T <= t) two tail (3.78146E-19) represents the probability that the absolute value of the t-Statistic (14.32850425) is larger in absolute value than the critical t-value (2.009575199) as well as 0. Thus, it can be stated that according to the t-criterion that the claim for alternative hypothesis is accepted ($| t | \geq t_{\alpha/2;\, v}$).

Furthermore, Table II reveals that the students enjoyed working with online video sessions than using reading materials and a perceived great confidence level in attending the concerned sessions was attained.

TABLE I. T-TEST RESULTS OF THE TWO FLIPPED CLASSROOM APPROACHES

t-Test: Paired Two Sample for Means		
	Video	*PPT slides*
Mean	69.13333333	48.01111111
Variance	43.50793651	157.962837
Observations	50	50
Pearson Correlation	0.559799717	
Hypothesized Mean Difference	0	
Df	49	
t Stat	14.32850425	
P(T<=t) one-tail	1.89073E-19	
t Critical one-tail	1.676550893	
P(T<=t) two-tail	3.78146E-19	
t Critical two-tail	2.009575199	

TABLE II. RESULTS OF THE SURVEY

	Video	Reading Material (ppt)
Enjoyed working on the requirement out of class	70	30
Engaged in interaction with others in class	40	60
Required more effort to perform activity	30	70
Required more time to follow the concept	40	60
Enjoyed the class activity	40	60
Confidence level was high after flipped session and before attending the class	70	30

V. DISCUSSION OF RESULTS

A. Discussion of findings and Answers to Questions Posed

In this section, the role of flipped classroom concept was analyzed and its tools in higher education for developing skills along with a comparative analysis of the two types of flipped classroom approaches: online videos and online lecture (reading) material were performed. From the results in Table I, it can be observed that the two approaches have significantly different means and huge differences between them. Online videos sessions was preferred by most of the students over online PowerPoint as a pre-class learning material to support the flipped-classroom approach. It was also observed that flipped classroom sessions were effective and played an instrumental role in the life of students in terms of developing related skills like problem-solving. The students were more confident and active with the proposed approach in contrast with the traditional way of teaching whereby students were hesitant to ask any query. Moreover, the students developed a critical understanding of the topics and were highly motivated in interacting with their faculty. This helped to develop better relationships and interaction among them. Furthermore, the overall perception and attitudes of students was changed, thus leading to increased student performance.

B. Study Implications

The present study is useful and effective for both the recent generation of students as well as teachers since they can investigate their perceptions on the concept of well-designed pre-class learning materials using the correct methods to support the flipped classroom concept. Besides, the study will pave the way for other researchers who are interested in this nascent establishment of teaching within the curriculum which in turn needs huge discussions with respect to updating the content of the curriculum. The study also helped in analyzing the effects and views of students with regards to the concept of flipped classroom thereby highlighting the role of integrating technology in educational systems along with their critical evaluation. Therefore, this study is crucial as an important medium of knowledge retention among students. It also highlights that the success of a flipped-classroom approach mainly depends on the type of pre-class content provided to the students.

For this study, we have assumed that the content and the quality of the content were up to the expected standards. The findings of this paper are in contrast with authors in [37] who claim that there is no difference between video lectures and text readings. In addition, this study also focused on the importance of using the correct format or medium to design the pre-class content which guarantees that a maximum number of students actively participate leading to a successful flipped classroom session.

VI. CONCLUSION AND FUTURE RESEARCH

This study presented a novel learning approach to the concept of flipped classroom. Two flipped classroom methods were analyzed and evaluated. The results show that the online videos method of teaching was mostly preferred to other methods. The study showed that the success of flipped classroom depends on how prepared students are to work and study with minimum guidance outside the class. This research shows that students clearly prefer video lectures or text or ppt slides lectures. The performance of the students who were assigned to view videos as pre-class content shows a significant improvement in performance as compared to students who used text or ppt slides as their pre-class content.

Thus, future research will be conducted based on data obtained from students who attend a flipped-classroom session throughout the semester for various subjects in the university. Furthermore, in future works, we hope to use qualitative study methods such as interviews and focus groups for teachers and instructors to get an elaborate and specialized viewpoint of instructors for content design strategies that could be used to support flipped classroom approaches. Another limitation of the study is that it did not take into account other specific skills like critical thinking, creativity, resilience, analytical reasoning, etc. which could affect the performance of students. Therefore, we recommend that an analysis incorporating a wide level survey capturing these different skill set of students be conducted.

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Handwriting Recognition using Artificial Intelligence Neural Network and Image Processing

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Abstract*—Due to increased usage of digital technologies in all sectors and in almost all day to day activities to store and pass information, Handwriting character recognition has become a popular subject of research. Handwriting remains relevant, but people still want to have Handwriting copies converted into electronic copies that can be communicated and stored electronically. Handwriting character recognition refers to the computer's ability to detect and interpret intelligible Handwriting input from Handwriting sources such as touch screens, photographs, paper documents, and other sources. Handwriting characters remain complex since different individuals have different handwriting styles. This paper aims to report the development of a Handwriting character recognition system that will be used to read students and lectures Handwriting notes. The development is based on an artificial neural network, which is a field of study in artificial intelligence. Different techniques and methods are used to develop a Handwriting character recognition system. However, few of them focus on neural networks. The use of neural networks for recognizing Handwriting characters is more efficient and robust compared with other computing techniques. The paper also outlines the methodology, design, and architecture of the Handwriting character recognition system and testing and results of the system development. The aim is to demonstrate the effectiveness of neural networks for Handwriting character recognition.

Keywords*—*Support vector machine; neural network; artificial intelligence; handwriting processing

I. Introduction

Handwriting digits and character recognitions have become increasingly important in today's digitized world due to their practical applications in various day to day activities. It can be proven by the fact that in recent years, different recognition systems have been developed or proposed to be used in different fields where high classification efficiency is needed. Systems that are used to recognize Handwriting letters, characters, and digits help people to solve more complex tasks that otherwise would be time-consuming and costly. A good example is the use of automatic processing systems used in banks to process bank cheques. Without automated bank cheque processing systems, the bank would be required to employ many employees who may not be as efficient as the computerized processing system. The handwriting recognition systems can be inspired by biological neural networks, which allow humans and animals to learn and model non-linear and complex relationships [1,2]. That means they can be developed from the artificial neural network [4]. The human brain allows individuals to recognize different Handwriting objects such as digits, letters, and characters [5]. However, humans are biased, meaning they can choose to interpret Handwriting letters and digits differently [8]. Computerized systems, on the other hand, are unbiased and can do very challenging tasks that may require humans to use a lot of their energy and time to do similar tasks. There is a need to understand how human-read underwriting [10].

The human visual system is primarily involved whenever individuals are reading Handwriting characters, letters, words, or digits. It seems effortless whenever one is reading handwriting, but it is not as easy as people believe. A human can make sense of what they see based on what their brains have been taught, although everything is done unconsciously. A human may not appreciate how difficult it is to solve handwriting. The challenge of visual pattern recognition is only apparent to develop a computer system to read handwriting [6,17]. The artificial neural networks approach is considered as the best way to develop systems for recognizing handwriting. Neural networks help to simulate how the human brain works when reading handwriting in a more simplified form. It allows machines to match and even exceed human capabilities at reading handwriting. Humans have different handwriting styles, some of which are difficult to read. Besides, reading handwriting may be time-consuming and tedious, especially when individuals are required to read several Handwriting documents by different individuals [25]. A neural network is the most appropriate for the proposed system due to its ability to derive meaning from complex data and detect trends from data that are not easy to identify by either other human techniques or human [23]. The main aim of this paper is to develop a model that will be used to read Handwriting digits, characters, and words from the image using the concept of Convolution Neural Network. The next sections will provide an overview of the related work, theoretical background, the architecture, methodology, experimental results, and conclusion.

A. Research Objectives

The main objective of this research is to design an expert system for Handwriting character recognition using neural network approach. Other objectives include:

- To address the issue of accuracy in Handwriting character recognition systems by developing a system that will use efficient technology for recognizing Handwriting characters and words from image media.
- To investigate and demonstrate the usefulness of neural network technology in development of efficient Handwriting character recognition systems.

B. Research Questions

This research is aimed to answer the following questions:

- What are the different techniques and methods used in Handwriting character recognition?
- How can the performance of Handwriting recognition systems be improved using artificial neural networks?

C. Target Group

This paper will be targeting university students and instructors who want to convert their Handwriting notes and papers into electronic format. Despite the increased adoption of digital technology in institutions of higher education, handwriting remains part of students' and instructors' daily lives. Students take Handwriting notes while listening to their lectures and take notes while reading from different sources. Some also note down their thoughts, plans, and ideas on their notes. Likewise, lecturers have Handwriting notes that they would want to communicate to students. Hence, this paper will be targeting students and lecturers to develop a system that will allow them to convert their Handwriting works into electronic works that can be stored and communicated electronically. The central assumption of this paper is that students and lecturers need to have copies of their works that are stored electronically in their personal computers. Further, handwriting with pen and paper cannot be entirely replaced by digital technology.

II. Theoretical Background

Handwriting character recognition is one of the research fields in computer vision, artificial intelligence, and pattern recognition [3,9]. A computer application that performs handwriting recognition can be argued to have the ability to acquire and detecting characters in pictures, paper documents, and other sources and convert them into electronic format or machine-encoded form. The system may obtain Handwriting sources from a piece of paper through optical scanning or intelligent word recognition. Also, the system may be designed to detect the movement of the pen tip on the screen. In other words, handwriting recognition may involve a system detecting movements of a pen tip on the screen to get a clue of the characters being written [7]. Handwriting recognition can be classified into two: offline recognition and online recognition. Offline handwriting recognition involved the extraction of text or characters from an image to have letter codes that can be used within a computer [15]. It involves obtaining digital data from a static representation of handwriting. A system is provided with a Handwriting document to read and convert the handwriting to a digital format. Online handwriting recognition, on the other hand, involved automatic detection or conversion of characters as they are written on the specialized screen [28, 35]. In this case, the system sensors movement of pen-tip to detect characters and words. Different methods and techniques are used to ensure that computer systems can read characters from Handwriting images and documents [32, 26]. Among the existing techniques that are used to model, and train Handwriting character recognition include neural network, Hidden Markov Model (HMM), Machine Learning, and Support Vector Machine, to mention a few. This paper focuses on artificial intelligence networks, machine learning, Hidden Markov Model, and the Support Vector Machine.

A. Artificial Intelligence

The idea of reading Handwriting characters, digits, and words by computer systems can be argued to be an imitation of a human being. In other words, such a system can be argued that they use artificial intelligence to read handwriting from images or any Handwriting source [11]. Artificial intelligence refers to intelligence that is demonstrated by machines [13]. The term is used to describe computer or machines that can mimic "cognitive" functions that are associated with the human mind. Artificial intelligence allows the machine to learn from experience, adjust to new data (inputs), and perform tasks that can be performed by humans [12, 20]. Branches of artificial intelligence include machine learning, neuron network, and deep learning.

B. Machine Learning

Machine learning technology is inspired by psychology and biology that focus on learning from a set of data. The central assumption is that machines can learn to perform given tasks by learning from data [21]. A machine learning model is provided with training data that is specific to the given problem domain and the solution to each instance of the problem. That way, the model learns how to solve certain problems based on learning [14]. Fig. 1 shows a simple demonstration of the machine learning model used in the handwriting recognition system. The model takes an image that has a Handwriting digit and determines the specific digit based on the learning data.

C. Artificial Neural Network (ANN)

Artificial Neural Network (ANN) refers to information processing paradigm or computing systems that are inspired by biological neural networks that constitute the human brain [18]. The systems are not identical to the biological neural systems, but they are designed to process information the same way the human brain and animal brain process information [27]. The networks are composed of many interconnected neurons working in unison to achieve specific goals [37]. Just like the human brain, ANN learns from example. Hence, an ANN can be configured for an application, such as data classification or character recognition through the learning process. The learning process involves adjusting the system to a connection [24]. The artificial neural network comprises a network of multiple simple processors, each with a small amount of local memory [39]. The processors (units) are linked together by unidirectional communication channels and operates only on local data and input their get through their links.

D. Biological Neuron and ANN

As indicated earlier, artificial neural networks are inspired by the biological neural system. Hence, learning how biological neurons works can help to understand the artificial neural network [16]. The human body's neural system consists of three stages: neural network, receptors, and effectors as shown in Fig. 2. The first phase is the receptor which receives stimuli from the external or internal environment and then passes the information to neurons [14, 16]. The second phase involves the processing of information by the neural network to make a proper decision of output. The third and final stage involves translation of the electrical impulses into responses to the external environment.

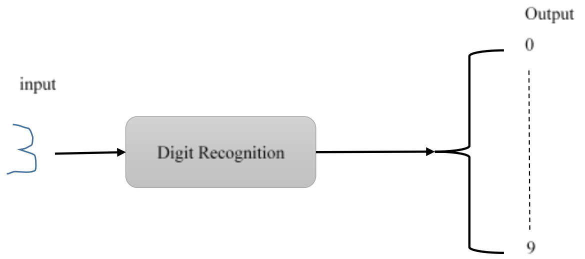

Fig. 1. Machine Learning Handwriting Model.

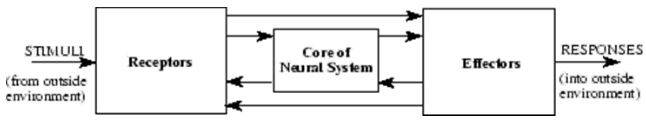

Fig. 2. Biological Neuron Model.

An artificial neural network can be argued to be a simplified imitation of the central nervous system. The structural constituents of human brains known as neurons perform computations such as logical inference, cognition, and pattern recognition, to mention a [19, 38].

The neuron models are shown in Fig. 3 and 4; however, does not do anything different that cannot be done by conventional computers. In other words, it is just a simple representation of a neural network system that does not do much different from what a traditional computer can do. The Fig. 5 presents a more complicated model (McCulloch and Pitts Model) which is different from the previous model since it has inputs that are "weighted" [17]. That means each input has a different effect on decision making. The weight of an input can be described as the number which when multiplied with the input, it results in weighted input [39]. The results are then added together, and if they exceed the certain pre-determined threshold value, the neuron fires, else, the neuron does not fire [29, 33].

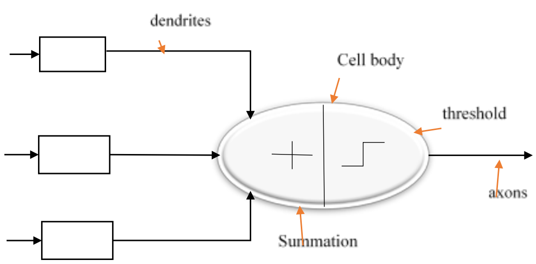

Fig. 3. Neuron Model.

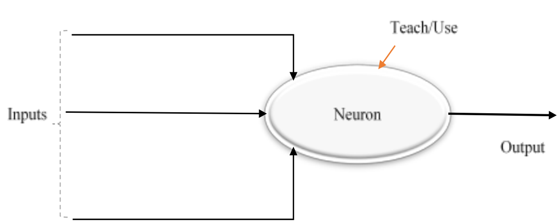

Fig. 4. Artificial Neuron Model.

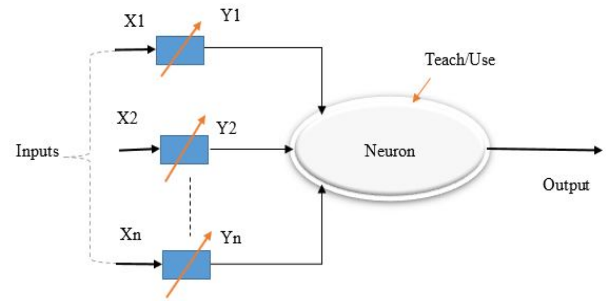

Fig. 5. Complicated Neuron Model.

Mathematically, neuron fires if and only if: **X1Y1+ X2Y2+…>Threshold**. The McCulloch and Pitts Model (MCP) neuron can adapt to different situations by changing its weights and/or threshold [17]. Various algorithms can be used to make neurons to "adapt," with Delta rule and the back-error propagation being the most used algorithms.

E. Deep Neural Network

The neural network has layers of units where each layer takes some value from the previous layer. That way, systems that are based on neural networks can compute inputs to get the needed output [29]. The same way neurons pass signals around the brain, and values are passed from one unit in an artificial neural network to another to perform the required computation and get new value as output [17]. The united are layers, forming a system that starts from the layers used for imputing to layer that is used to provide the output. The layers that are found between the input and output layers are called the hidden layer. The hidden layers refer to a deep neural network that is used for computation of the values inputted in the input layer. The term "deep" is used to refer to the hidden layers of the neural network [25] as shown in Fig. 6. In Handwriting character recognition systems, the deep neural network is involved in learning the characters to be recognized from Handwriting images [33]. With enough training data, the deep neural network can be able to perform any function that a neural network is supposed to do. It is only possible if the neural network has enough hidden layers, although the smaller deep neural network is more computationally efficient than a more extensive deep neural network [19].

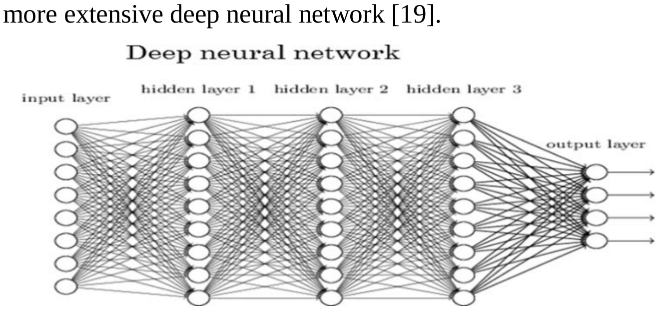

Fig. 6. Deep Neural Network.

F. Hidden Markov Models (HMM)

Hidden Markov Model (HMM) has been used in many handwriting recognition systems as a primary modeling component. It is essential to examine the theoretical background of this model to have a clear understanding of how handwriting recognition systems work [31]. HMM is a statistical Markov model that is used in a system that is supposed to assume the Markov process [40]. It can be considered as the most straightforward dynamic Bayesian network. Hidden Markov Models are class pf probabilistic graphical models used for predicting a sequence of hidden variables from a set of observed variables [15]. For instance, these types of models can be used to predict the weather based on the types of people's clothing. The weather, in this case, is the hidden variable while the people's clothes are what has been observed (known) [40]. In the same way, HMMs have successfully been implemented in the speech recognition, and character recognition since the models can help systems to predict unknown from the observed [23]. The fact that handwriting can be a statistical model is the main reason HMM can be argued to be one of the most preferred models in the development of Handwriting character recognition systems [30].

G. Support Vector Machine

Handwriting recognition can be considered as a problem of supervised learning and classification from a discriminative classifier point of view, with this assumption, Support Vector Machine which a discriminative classifier is considered as one of the models that can be effective in developing handwriting recognition systems [34]. Like a neural network, a support vector machine is a subset of machine learning [36]. The support vector machine refers to a supervised learning model that is dependent on learning algorithms for classification and regression analysis. A support vector machine can be considered as a computational algorithm that finds out a hyper-plane or a line in a multidimensional space that separate classes. The separation between two or more linear classes can be achieved by any hyperplane [2,17]. This method is known as linear classification. However, several hyperplanes can be used to classify the same set of data, as shown in Fig. 7. A support vector machine is an approach where the main aim is to find the best separation hyperplane.

The comparison of all approaches is shown in Table I below.

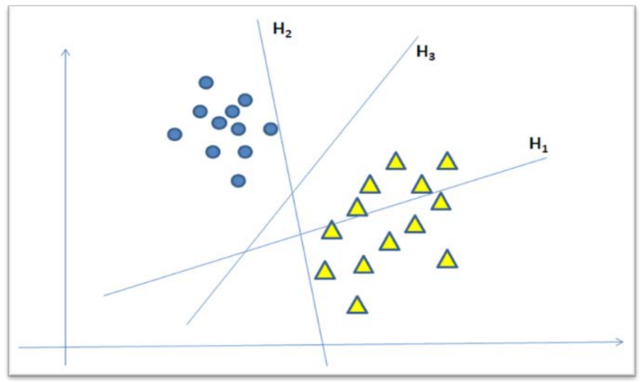

Fig. 7. Support Vector Machine Hyperplane.

TABLE I. COMPARISON OF APPROACHES

Approaches	Description	Advantages	Disadvantages
Hidden Markov Models (HMM)	HMM is a statistical Markov model which is used in a system that is supposed to assume the Markov process	-Strong statistical foundation [31]. -It allows a flexible generalization of sequence profiles [40]	-Have many unstructured parameters. -Algorithms are expensive in terms of computational time and memory [15] -Training requires repeated iterations, and this can be time-consuming [19]
Machine Learning	Machine learning-powered systems rely on patterns and inference instead of explicit instruction to read text and characters [21]	-No human intervention needed [27]. -Allows continuous improvement [19]	-Requires massive data to train [21] -Expensive in terms of time and resources [27] -High-error susceptibility [31]
Neural Network	A neural network can be considered as a large parallel computing system comprising of many interconnected nodes.	-Can learn complex non-linear input relationships [35]. -Has self-organizing capability [16]. -Ability to work with incomplete knowledge -Parallel processing capability -Ability to make machine learning	Different training may damage the capability of the system Overreliance on hardware [22]
Support Vector Machines (SVM)	Classifies the data using a hyperplane	Unlike neural networks, SVM approach relies on learning examples and structural behavior [23]. Has better generalization due to structural risk minimization	It is difficult to select a "good" kernel function Difficult to understand and interpret It is hard to visualize the impact of SVM models.

IV. Design and Architecture

This section discusses the design and architecture of the proposed handwritten character recognition system that will be using the neural network approach. The proposed system comprises input pre-processing, CNN, and output sections as shown in Fig. 8.

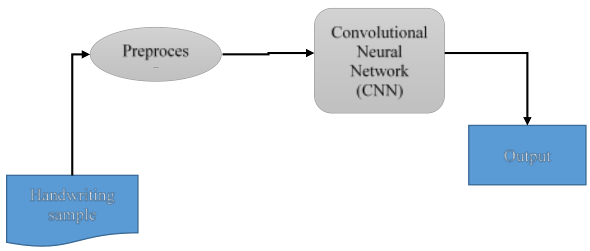

Fig. 8. Handwriting Recognition System (HRS) Design.

The explanation of the architecture is provided below:

A. *Neural Network Arthictecture*

As indicated earlier, the HRS systems are most efficient when they are based on neural networks. Hence, there is a need to understand the neural network architecture. The neural network architecture refers to the elements that are connected to make a network that is used for handwriting recognition. The human brain works loosely to inspire neural networks. It is based on the idea of how neurons pass signals around the human brain to process input into an output [16]. Several units are layers to form a network and arrange from the ones that are responsible for receiving input to the layer that is responsible for output values. Between the output and input level layers, there is a hidden layer that is involved in much of processing. Different neural network architectures can be used to provide different results from the input images of handwriting. It is because architectures are based on different parameters, data, and duration of training. Fig. 9 shows a clear visualized of architecture used to recognize handwriting from images. The "X" shows the input while "Y" represents the output.

The size of a deep neural network layer is dependent on the work that the system is supposed to do. However, in most cases, more computational efficient smaller hidden layers can be developed to achieve the same task as one that can be achieved with an exponentially large deep neural network [35]. The deep neural network is supposed to memorize the training data to be able to recognize handwriting. Hence, deep neural networks are commonly used in optical character recognition systems.

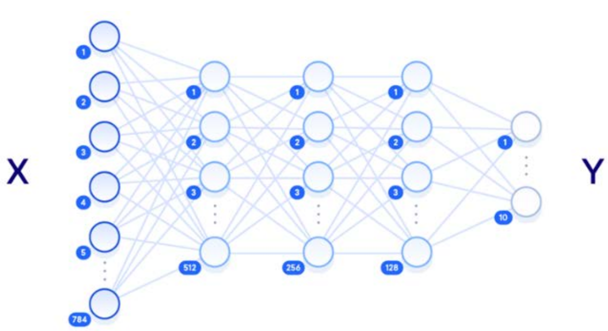

Fig. 9. Neural Network Architecture.

B. *Convolutional Neural Network*

The system will use the convolutional neural network (CNN), which class of deep neural networks that are used for character recognition from images. Fig. 10 shows an underlying architecture of CNN that will be used in the OCR system. The architecture shows different types of layers, with the first layer being the input layer and the last layer being the output layer. The second later is called the convolutional layer and is followed by pooling layers and convolutional layers. The description of the CNN architecture is as follows:

1) Input layer: The input layer is used to feed the system with the image with the handwriting. The layer can be colored image (RGB values) or grayscale. It can have dimension W*H*W, depending on the input image. The W*H refers to the width and height of the image, while D refers to the depth of the image.

2) Convolution layer: The convolution layer is the building block of the whole network. Most of the computational work that is required to recognize characters from the input is done in this layer (Aggarwal, 2018). The layer consists of a set of learnable filters known as parameters of the convolution layer.

3) Pooling layer: The pooling layers are found between the convolutional layers in the CNN architecture. They are responsible for progressively reduce the spatial size of computational work in the network. They help to streamline the underlying computation. They do so by reducing the dimension of the input data by combing the outputs of the neuron clusters. They operate independently. That way, the system can achieve the intended outputs.

4) Fully connected layer: Neurons in a fully connected layer are fully connected to all activations in the prevision layer. Hence, this layer, activations, can be computed with matrix multiplication. Based on the architecture, a system can have multiple fully connected layers. In summary, CNN can be used to achieve a solution to every pattern recognition issue. The architecture demonstrated above shows how OCR systems using neural networks can read handwriting. The convolutional networks work in the hierarchy and can be used to solve complex structures found in handwriting inputs. Humans inspire the whole idea can recognize writing objects and process what they see in their brains.

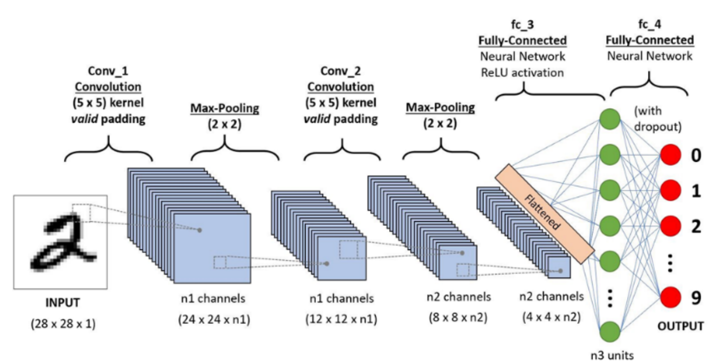

Fig. 10. Convolutional Neural Network Architecture.

V. METHODOLOGY

The current OCR system will consist of five phases. The phases are image acquisition and digitization, preprocessing, segmentation, feature extraction, and recognition. Fig. 11 shows the methodology that will be used to read handwriting.

A. Image Acquisition and Digitization

The image acquisition step involves acquiring an input image that contains handwriting. The image, in this case, should be in specific formats such as PNG and JPEG. The image is acquired through a digital camera, scanner, or any other suitable input device. The digitization step, on the other hand, involves converting the input paper into electronic format [20]. The conversion is achieved by first scanning the original document and representing it in the form of an image that can be stored on a computer. The digital image is essential for the pre-processing phase.

B. Preprocessing

Preprocessing is the second phase of OCR after the digital image has been made as shown in Fig. 12. The digitized image is pre-processed to remove noise, and then it is checked for skewing. Preprocessing is essential for developing data that that are easy for optical character recognition systems. The main objective of pre-processing is to remove the background noise, enhance the region of interest in the image, and make a clear difference between foreground and background.

1) Image enhancement techniques: To modify attributes of the image to make it more suitable and to improve the quality of the image by reducing noise, increasing contrast, image blurring, and providing more details. Hence, to process an image so that result is more suitable than the original image and providing better input for automated image processing techniques.

2) Noise removal: Addictive noises of different types can contaminate images. Hence there is a need to remove noise to improve the quality of the image.

3) Binarization: This method is used to transform the grayscale image and converting it to black and white, substantially reducing the information contained within the image from different shapes of gray into a binary image.

4) Normalization: This process in image processing that changes the range of pixel intensity values. Its common purpose of converting an input image into a range of pixel values that are more familiar to the senses. Normalization involves converting images into a standard size.

5) Skew correction, thinning: This is one of the first operations to be applied to scanned documents when converting data to digital format. This process helps to get a single-pixel width to allow easy character recognition.

Preprocessing for handwriting characters of current approach is shown in Fig. 13.

C. Segmentation

Segmentation can be argued to be the most critical process in character recognition techniques. Segmentation of images is done in the testing stage only. It checks for any error point inclusion by checking all points against the average distance between segmentation points incomplete image. The process involves separating individual characters from an image, as shown in Fig. 14. The process results in multiple segments of the image known as super pixels. The main aim of segmentation is to simplify the representation of an image into something that can be analyzed easily. Hence it has a positive impact on the recognition rate of the script.

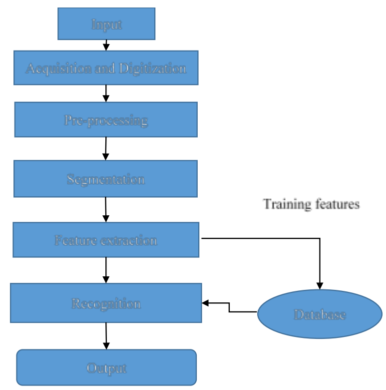

Fig. 11. OCR System.

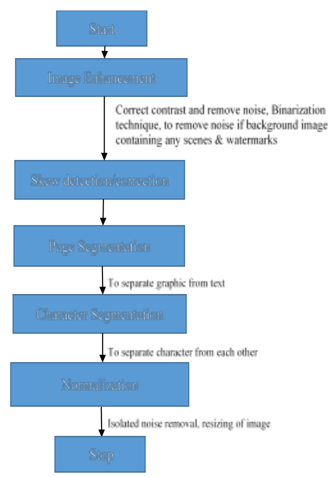

Fig. 12. Preprocessing Techniques.

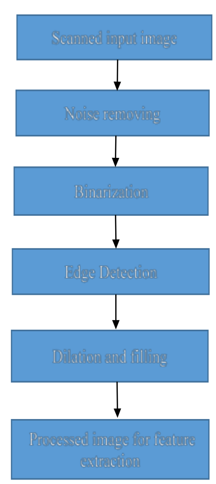

Fig. 13. Preprocessing of Handwriting Characters.

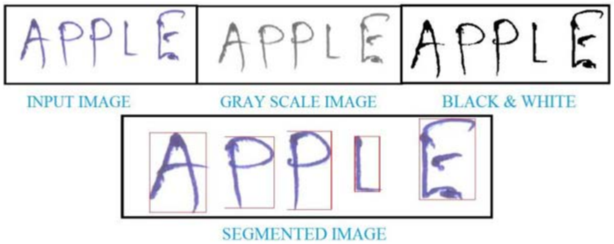

Fig. 14. Example of a Segmented Image.

D. Feature Extraction

In this phase, features of the image are extracted and are defined based on the following attributes: height of the character, numbers of horizontal lines, widths of the character, number of circles, pixels, position of different features and number of vertically oriented arcs, to mention a few.

E. Recognition

In this phase, the neural network is used for classification and recognition of the characters from the image. The most neural networks that are used by optical character recognition systems are the multiplayer perception (MLP) and Korhonen's Self Organizing Map.

VI. Testing

This section presents the testing and results of the OCR system. The testing subsection will present the indications on the correctness and functionality of the OCR system. The aim is to provide relevant information that will be useful to critical users. The information is about the quality of the system. The results subsection, on the other hand, highlights indications that the system was successfully implemented.

A. Unit Testing

Unit testing was used to test individual units of the system. The testing focused on the following: image acquisition and digitization, preprocessing, segmentation, feature extraction, and recognition modules. Unit testing was vital since it was the first testing effort performed on code. The testing helped to identify bugs in the code and made it easy to fix the code. Early detection of bugs in code is the most effective way of ensuring that the right system is developed. It helps to avoid the costs of fixing a faulty system later in the development process. Developers make sure that every unit is functioning as expected.

The following list of functions of unit testing that were tested:

- Select the scanned input image of Handwriting document/images
- Applying pre-processing
- Apply segmentation
- Apply feature extraction
- Extract digital character

B. Integration Testing

Individual units of the systems were combined and tested as a group or unit. Input models tested in unit testing were targeted in this type of testing. The main aim was to expose faults in the interaction of the integrated units. The integration testing mainly focused on interfaces and the flow of data between integrated system units. Different from unit testing, integration links were given more priority. The main benefits of integration testing include:

- Making it easy to integrate different system module.
- Allowing faster development and increases developers' confidence.
- The testing is easy to conduct.
- Helps to test the system for real-work cases.
- It makes it easy to discover issues such as a broken database.

C. Validation Testing

Validation testing was conducted to determine whether the development process meets specified requirements. Validation testing has the following benefits:

- The testing will help to identify defects in the system.
- Validation testing is essential since it helps to understand the functionality of the system better.
- The testing ensures that the right system is developed based on the specified requirements.

D. GUI Testing

GUI testing was conducted to ensure that the system's graphical user interface meets the specified specification and is user-friendly. GUI testing has the following benefits:

- The testing helped to identify regression errors.
- The testing helped to reduce the margin of errors.
- Helped to increase the efficiency of handwriting character recognition.
- The testing helped to ensure that GUI is user-friendly.

VII. Results and Discussion

The OCR system was used to recognize Handwriting characters and digits. As indicated earlier, it was implemented using a neural network. The following were the expectations of the system:

- The system will have the capacity to show single word recognition. It will be an indication that the training was done correctly.
- The system will show more than one-word recognition (sentence recognition). It will also be an indication that the system was well trained. The recognition should be at least 99.9 percent accurate.

- The system will show characters that it was not able to recognize well or characters that were not well trained. The system will recognize special characters and digits.

A. Dataset and Feature Selection

The dataset has sample Handwriting digits for evaluating machine learning models on the problem of Handwriting digit recognition. It contains 21,000 testing and 21,000 training of Handwriting digits from (0 to 9). Each of the digits is standardized and cantered in a grayscale (0 – 255) images with a size of 28x28 pixel. In each of the images consists of 784 pixels that represent the structures of the digits. A sample of dataset is shown in Fig. 15.

B. Digits Recognition

The decision tree classification model was used to train more than 42,000 datasets. The dataset was split into two halves; half of the datasets for the training set and the remaining half for training sets. The following steps were performed for the classification on Handwriting digits dataset:

- Load the datasets of Kaggle Handwriting digits for classification.
- Split the datasets into two sets; one for training and other for testing.
- The recognizer was trained to predict that given an image of Handwriting digits.
- Test the accuracy of the classifier as shown in figure.

The python code for digits recognition is shown in Fig. 16, and OCR result in Fig. 17.

C. Model Accurary Results

Fig. 18 shows the list of model testing after training the machine learning model on the dataset. It further shows that some of the digits were not recognized by the machine learning model. The machine learning model was trained with a dataset that contains 42,000 rows and 720 columns, which the result shows 83.4% accuracy. The digit images pixels are used as features vector and decision tree as classifiers. Moreover, data repository is used for training and testing the datasets so, the result shows that the decision tree classifier is effective in recognition of Handwriting digits. The accuracy of decision tree classifier is shown in Fig. 19 and 20. The digit 1 was recognized with the highest accuracy of 93.73 whereas digit 0 was having least accuracy of 83.56.

Fig. 15. Sample from Dataset.

Fig. 16. Python Code for Digits Recognition.

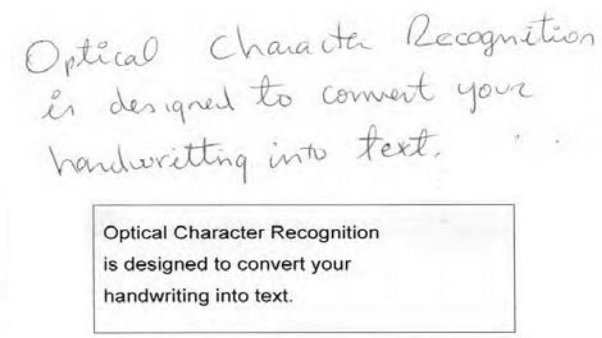

Fig. 17. OCR Results.

Handwritten Digits images/Test Data	System Digit Prediction	Actual Expected Prediction
	Correctly Predicted	0
	Correctly Predicted	0
	Correctly Predicted	0
	Wrongly Predicted	0
	Wrongly Predicted	6
	Correctly Predicted	6
	Correctly Predicted	6
	Correctly Predicted	6

Fig. 18. Digit Prediction of Handwriting Images.

HandWritten Digits(0-9)	Accuracy of the Classifer (100%)
0	83.56
1	93.73
2	83.69
3	83.73
4	83.81
5	83.65
6	83.47
7	83.81
8	84.12
9	83.75

Fig. 19. Accuracy of Decision Tree Classifier for Digits.

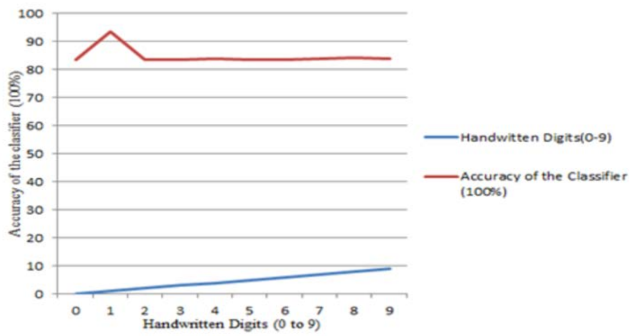

Fig. 20. Accuracy of the Decision Tree Classifier (Visual).

VIII. Conclusion

The main aim of this research was to develop a system that will help in the classification and recognition of Handwriting characters and digits. Recognition of characters and digits is vital in today's digitized world, especially in organizations that deal with Handwriting documents that they need to analyze using computer systems. Systems that are used for classification and recognition of handwriting help organizations and individuals to solve complex tasks. The current system used neural networks to process and read handwriting characters and digits. The system benefited from Convolution Neural Networks (CNN) with the help of training data that allowed easy recognition of characters and digits. Like the human visual system, CNN allowed the OCR system to be more sensitive to different features of objects. That way, it was easy to classify and recognize different Handwriting characters and digits based on the training data stored in the system's database. The phases of handwriting recognition included image acquisition, digitization, preprocessing, segmentation, feature extraction, and recognition. The system was tested using unit testing, integration testing, GUI testing, and validation testing. The final system satisfied the specified requirements of accuracy as well as recognition. The work of the current research can be extended for character recognition in other languages. It can be used to convert books, newspapers, handwritten notes, and newspapers into digital text format using machine learning models used by the current research.

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Tai Chi Care: An Exergaming Software using Microsoft Kinect V2 for Blind or Low Vision Person during Confinement

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***Abstract*—Blind or low vision people need to practice activities for their mental and physical health to minimize the risk of suffering from articulation pain but they have problems due to difficulties and inaccessibility of displacement especially during the COVID-19 pandemic where everyone in this world was asked to stay at home during confinement. To solve these problems, we have developed a software tool for a care Tai Chi exergaming to encourage them to practice exercise at home using body tracking by Microsoft Kinect V2 and audio feedback. This software acts as a Tai Chi treatment, teaches four poses, and has a customized audio feedback to help person to understand each pose and generates progress graphs to evaluate the success of these exercises. We used the SDK libraries of the Kinect to obtain 3D joint position from sensors of the Kinect to calculate the angles and distances between joints to help the person to position in front of the Kinect, evaluate the different gestures of flexions and extensions of knees and elbows of each exercises, and body balance direction to avoid falling risk. These exercises have been evaluated with persons who are blind or low vision to improve feasibility and feedback.**

Keywords—Tai Chi; COVID-19; visual impaired; physical exercise; exergaming; audio feedback; Kinect; body tracking

I. Introduction

Tai Chi Chuan is a Chinese martial art that focuses on incorporating body movements, mind adjustments and breathing in one practice. Indeed, it is theoretically the manipulation of the good flow of the body in order to control bodily functions.

Several studies have shown that the practice of Tai Chi in elderly and middle-aged persons allows them to benefit from ideal bodily functioning and as well as prevention against various diseases. This practice leads to the improvement of cardiac and pulmonary functions [1]. Physical activity, of course, does not protect against the risk of contracting COVID-19 in case of exposure to the coronavirus. However, good physical condition contributes to the proper functioning of the immune system so that it can fight the virus. Tai Chi also helps support muscles and tendons [2] and reduce the deficit in bone density [3].

As well, Wu and his colleagues [4] focused on the patterns of muscular action during exercise. They analyzed the approach of Tai Chi and its consequences on balance, flexibility as well as strength. As in [5], they highlighted a virtual environment, which imitates the execution of the exercise by a Tai Chi master, which can provide the teacher with new ways to improve his skills.

Different studies are done on the practice of Tai Chi on different categories of people but they have not been interested in visually impaired or blind people who also need it to do physical exercises and especially when it is mainly dedicated to therapeutic care. For example, [6] a study examines the effect of practicing Tai Chi during one year on the physical functioning of the elderly, which is effective in maintaining and improving the state of physical condition of old people. However, it should be done at least three times a week to guarantee this effect. In [7] the Microsoft Kinect is used to record the spatial coordinates of the joints of the upper limbs of the body during the practice of Tai Chi Chuan as well as the data in order to perform a quantitative and qualitative analysis of the joint positions and the angle of the elbow joint. A study was conducted by [8] with participants from a trial on the effects of a 12-week Tai Chi training on the risk of ischemic stroke in the elderly, and this study showed that regular exercise Tai Chi can have positive benefits in terms of improving physical health and mental state of elderly.

Another study presented in [9] provides evidence that choosing Tai Chi Chuan as a form of exercise is beneficial for children with asthma, indicating that 12 weeks of exercise improve the quality of life for these children, improves pulmonary function and decreases airways inflammation. In addition, in [10], the authors are presented a qualitative research on the physical and psychosocial effects perceived on the practice of Tai Chi Chuan on an educational group in a clinical trial of patients suffering from chronic heart failure.

Physical activity is very important in our daily lives. In fact, it helps us to protect our health from various diseases and syndromes. Thus, many studies particularly address the importance of physical training to improve the health of people and maintain them in a better physical condition. Especially during the last COVID-19 epidemic where almost the entire world population was forced to respect the confinement and to stay at home, which is not arranged health either physically or psychological. This situation has generated in many people a depressed mood and generalized anxiety. Indeed, the prohibition and the deprivation of liberty directly confront people with feelings of weakness. Besides, being forced to stay at home is not natural for anyone and everyone has a basic need to feel free to do what they want.

For the blind or those with reduced vision, it is difficult to practice sports activities without being helped by another person because of the risk of falling and being injured and to correct they positions for those had difficulties. These people also suffer from being deprived of video games. These two shortcomings cause for these people: problems of physical balance (lack of sports activity) and psychological balance (Boredom and routine).

The repeated practice is supposed to recycle posture, encourage circulation throughout the body of people, maintain flexibility through their joints, and reduce the incidence of depression and discomfort for the visually impaired and improve their quality of life.

In particular, the use of video games for re-education (exergaming) is playing an increasingly important role towards its positive impact on patient attitudes and has been necessary to improve and maintain both their strength and especially their mobility [11]. This is an ideal solution during confinement due to the COVID-19 virus which has put us in stressful and restricted movement conditions. Indeed, sitting and walking too little increase the feeling of heaviness in the legs and pain even for people who do not have circulatory problems. To improve the blood flow in the legs, it is recommended to do certain sports exercises.

Among the many Motion Capture (MoCap) sensors, Kinect is the most prominent tool for medical applications and especially those related to physiotherapy [12, 13] that can be used for preventive purposes when detecting falls of the aged people [14], or rehabilitation exercises dedicated to people with temporary disability following a cardiovascular attack, or with limited mobility, etc.

In this paper, we will detail the tools and the system used in Section II. In Section III, we will present the results of the Tai Chi care exercises with a graph, which details the variation of the angles and the success rate. This part will be followed by a discussion in Section IV. We will end with a conclusion in Section V.

II. Materials and Methods

In order to interact and immerse in video games, Microsoft invented the Kinect in several versions. The second version (Fig. 1(b)) of this device allows connection and interaction by detecting different gestures and movements of the human body for Microsoft X-Box ™ platforms (Microsoft Corp., Redmond, WA, USA). In order to allow passionate programmers to create their applications, Microsoft has developed SDK software [15].

As we said before, the Kinect exists in several versions. Indeed, different publications have concentrated on the study of the different uses of the first version (Fig. 1(a)) of Kinect (V1) [16, 17]. Some of them had to face the limitation of precision of this first version [18] in particular with regard to the measurement of the angle of articulation, which has been improved in recent studies giving satisfactory results [19]. It also presents some detection and tracking problems in certain lighting situations, thus rendering it totally devastated by the second version of Kinect (V2) [20]. Therefore, in terms of accuracy, it has been validated that the Kinect V2 is much more precise than the previous one, thus allowing better results during new studies and giving the possibility of adaptation for new exercises intended for several disabilities or medical problems such as patients with balance disorders [21].

Table I presents a comparison between the different characteristics of the two versions of the Kinect sensor; it shows that the second version is more precise and that it has a wider field of vision than the first.

However, in our research, skeletal tracking is the application offered by the Kinect that interests us the most. Indeed, it is feasible from depth maps to obtain skeletal data of up to six users at a time, and this thanks to the automatic learning algorithms [22]. These data we just mentioned are composed of 25 points joined by different segments. This version also allows us to deduce the position of an invisible joint that can be hidden during detection by an object or a piece of furniture.

The exercises used in our work were performed by blind or visually impaired people in a standing position in front of the Kinect sensor. Users are invited to position themselves in the Kinect detection field in order to avoid the risk of loss of skeletal data of the joints of interest.

(a) (b)

Fig. 1. Kinect Sensors: (a) Kinect V1; (b) Kinect V2.

TABLE I. Characteristics of Kinect V1 and v2

Feature	Kinect V1 Xbox 360	Kinect V2 Xbox One
Color Camera	640 x 480 , 30 fps	1920 x 1080 , 30 fps
Depth Camera	320 x 240 , 30 fps IR depth sensor	512 x 424 , 30 fps Time of Flight (ToF) depth sensor IR can be used at the same time as color
Range	0.8m to 4m	0.5m (1 ft) to 4.5m (14.7 ft)
Angular field of view	57° Horizontal 43° Vertical	70° Horizontal 60° Vertical
Audio	16 bit per channel with 16 kHz sampling rate	16 bit per channel with 48 kHz sampling rate
Skeletal joints	20 joints	25 joints
Skeletons traked	2	6
Vertical adjustment	Tilt motor with ±27°	Manual (±27°)
Latency	~100ms	~50ms
USB	2.0	3.0

This work is based on the precision of the Microsoft Kinect SDK v2.0 libraries in order to obtain 3D joint positions in order to make the necessary calculations of distances and angles to set the conditions for the evaluation of Tai Chi.

$$\text{distance} = \sqrt{\left(X_{first}-X_{second}\right)^2+\left(Y_{first}-Y_{second}\right)^2+\left(Z_{first}-Z_{second}\right)^2} \quad (1)$$

Where $Joint_{first} = (X_{first}, Y_{first}, Z_{first})$ and

$Joint_{second} = (X_{second}, Y_{second}, Z_{second})$

$$\text{angle} = \frac{180}{\pi}\arctan\frac{|\vec{u}\times\vec{v}|}{\vec{u}.\vec{v}} \quad (2)$$

Fig. 3 represents the flowchart of the system, which is mainly based on skeletal data extracted from depth images by applying the random decision forest algorithm to detect joints [22]. Thus, after the acquisition of the x, y and z coordinates of the various joints of the skeleton, a calculation of the distances along the Z and X axes between the joints of the ankle and of the sensor (Fig. 2), is carried out to position the user in front of the Kinect and in its detection fields for a good detection of the skeleton and to widen a maximum of fields for the movement of the user without loss of skeletal data.

Also a calculation of distance between two points as indicated by equation (1) for the body balance calculation which is defined by calculating the distance between two joints of the torso, to warn the user if he is leaning or not and in which direction to return to his steady state in order to avoid the risk of falling. This step is evaluated in 4 directions along the X and Z axes, which are North (front), East (right), South (back) and West (left).

The angle associated with each articulation of interest was calculated by defining a couple of vectors $(\vec{u}, \vec{v}) \in R^3$ formed by the adjacent body sections of the joint and taking the angle in degrees between them, as presented by equation (2). Then, a skeleton overlay on the color image is displayed in real time on the computer screen with audio feedback from the speakers to instruct the user using voice notification.

The four exercises used in this work are represented in the Fig. 4, which are composed of a set of gestures. There are organized like this, the first exercise (Fig. 4(a)) the "Handing Ball pose" which consists of a movement motion of the arms which are in front of the body forming a circle as if there was a ball between them and which does not exceed the breast levels; this means that the conditions apply on the position of all the joints of the two arms (Shoulder, Elbow, Wrist, Hand and Hand-Tip), as well as a gesture to the legs which require a slight bending of the knees to have an angle for the two knees joints which is less than 180° and higher than 100°.

The second exercise (Fig. 4(b)) the "Qi pose" which is composed of a knee flexion gesture like that of the first exercise and a gesture for the hands which make a form of "qi", it means that both hands should be in front of the torso and bended, one between the "spine Shoulder" joint and the "spine Mid" joint and the other between "spine Mid" and "spine base" with the palms facing each other as if there is a small object between them.

The third one (Fig. 4(c)) is the "Ma Bu pose", it requires two gestures: one for the knees which must be bent by an angle of 90° and the other for the hands which are the level of the pelvis, this means the joint of the "hip".

In addition, the last exercise (Fig. 4(d)) is the "Gong Wu pose" which is made with a hand gesture like the previous one and a leg gesture so that one is in front and forms an angle at the knees of 90° and the other at the back and straight with an angle of 180°.

These exercises are used for the flexibility and the rehabilitation of different joints of body. They help to make the joints more flexible, especially the knee joints and to balance the body. The two first poses are specially intended for the arms joints, and the other are for the legs joints. Fig. 5 shown an example of screenshot for each exercise.

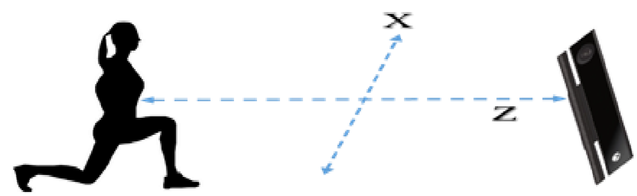


Fig. 2. Distance between Kinect Sensor and the user.

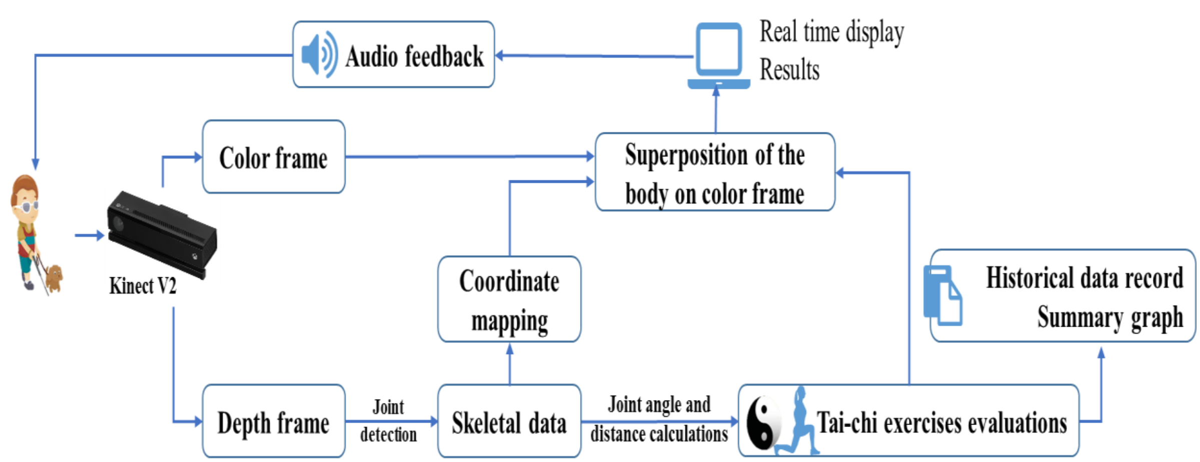
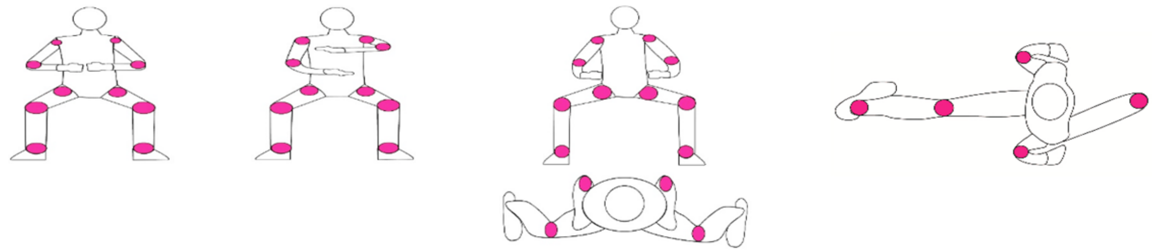


Fig. 3. Flowchart of Care Tai Chi Exercise for Blind or Visually Impaired Person.



(a) (b) (c) (d)

Fig. 4. The Four Care Tai Chi Exercises used in this Work: (a) Handing Ball Pose; (b) Qi Pose; (c) Ma Bu Pose; (d) GongWu Pose.

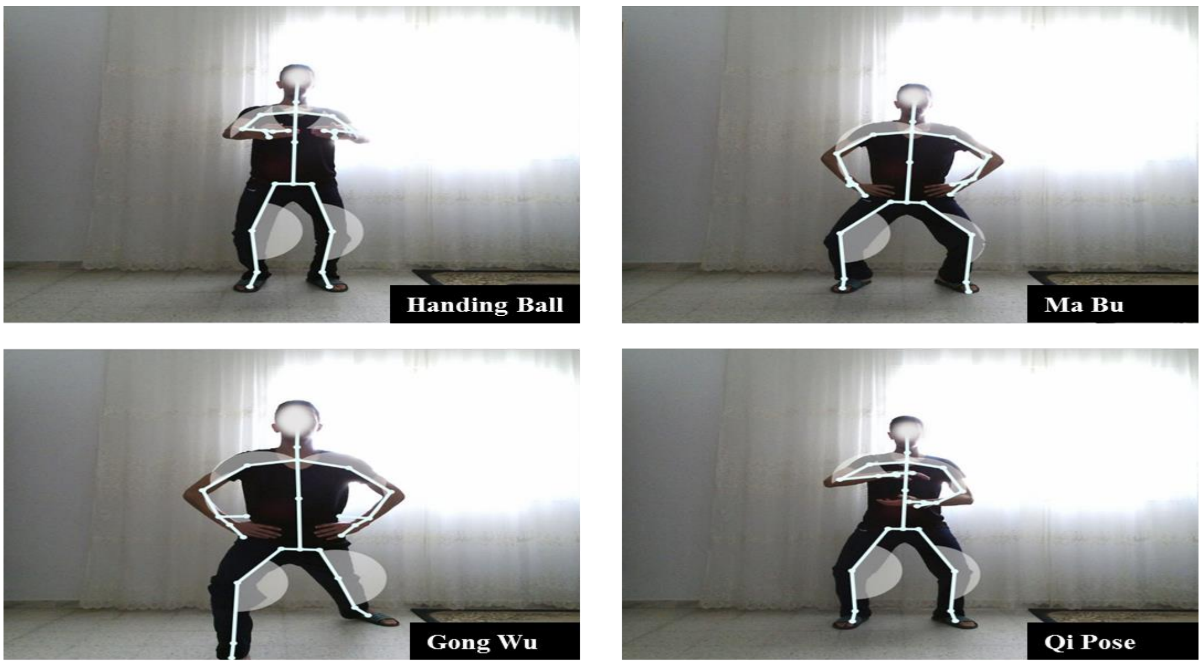


Fig. 5. Screenshots of the Four Care Tai Chi Exercise.

III. Results

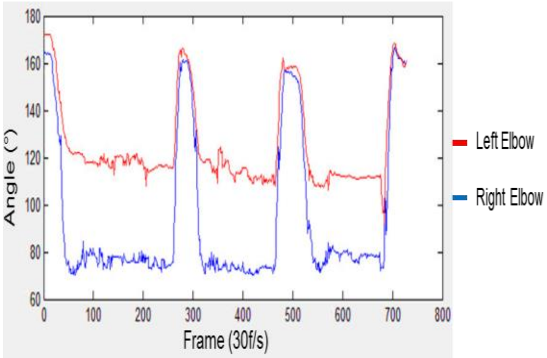
Fig. 6 shows sample graphs for each exercise. The knee flexion for the "Handing Ball" and "Qi pose" exercises is defined below 175°, for that of the "Ma Bu", it is limited between 70° and 120° because the position is difficult since it is hard to bend the knees by 90°, with regard to the "Gong Wu" the bending of the leg in front must be between 85° and 95° as for that in the back, it must be greater than 165°. These conditions are imposed after advice provided by a Tai Chi referee while taking into account the limitations of the mobility of blind or partially sighted people.

To facilitate the gestures of these four caring exercises, everyone is asked to repeat each exercise three times for a period of five seconds each time. These exercises deal with the flexibility of the knees and also the elbows. This set of different gestures is performed successfully but with a slight difference, in fact this is due to the difficulty of certain gestures for some people.

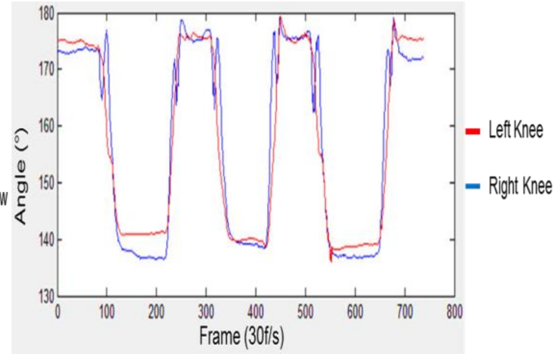
Regarding the success rate of elbows for witnesses, it is 100%. For the knees, this rate is divided into two parts, one for the "Handing Ball" and "Qi position" exercises where it is 100% and for the "Gong Wu" and "Ma Bu" exercises where it is only 80 %. This is at the beginning of the practice of these exercises, but after a few days of application, they can perform them successfully.

Verbal correction or instructions differ between gestures. Some of these have more correction than another depending on the difficulty of the exercises. For example, as already mentioned for knee flexion gestures in the poses of "Ma Bu" and "Gong Wu", also for the gesture of the positions of the hands for the poses of "Qi" and "Handing Ball".

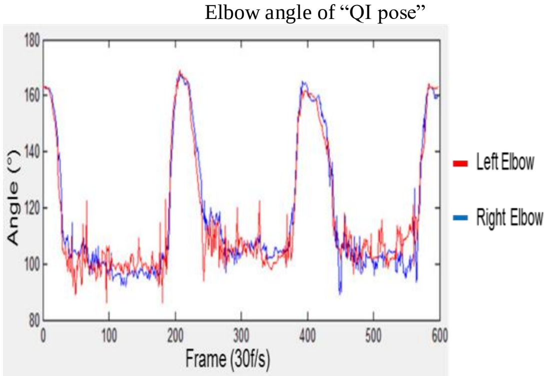
Fig. 7 shows the success rate of the tests carried out by the volunteers based on the number of correction and comprehension of the voice instructions according to the three executions of the test.



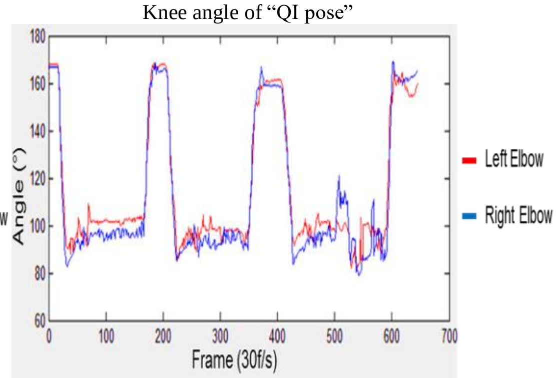
Elbow angle of “QI pose”



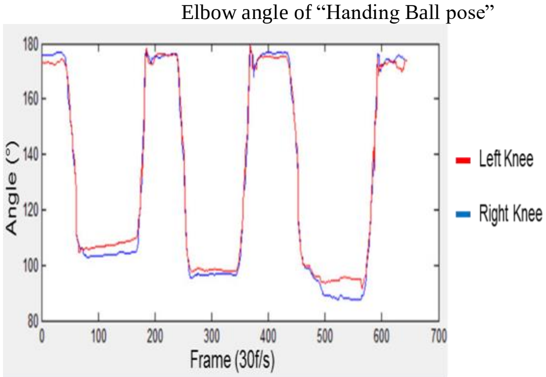
Knee angle of “QI pose”



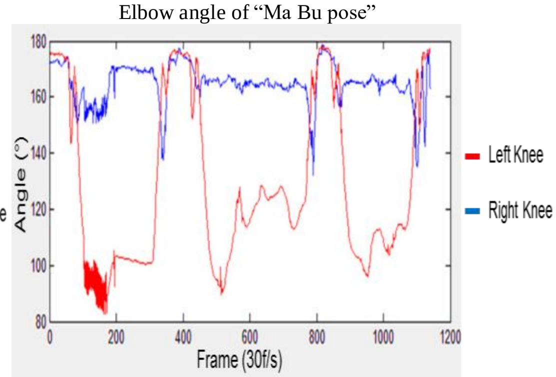
Elbow angle of “Handing Ball pose”



Elbow angle of “Ma Bu pose”



Knee angle of “Ma Bu pose”



Knee angle of “Gong Wu pose”

Fig. 6. Joints Angles Graphs.

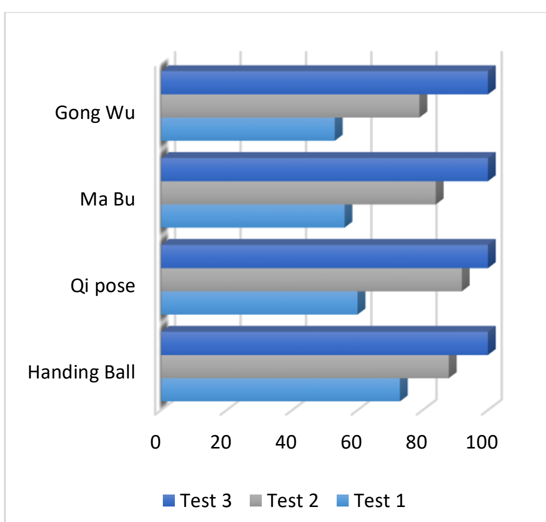


Fig. 7. Exercise Achivement Rate (%).

As mentioned in the previous section, these exercises are healing exercises to maintain the flexibility of the joints due to lack of mobility and especially the knees. This is why these gestures are based on the angle of the knee. Also, do not forget that people who are blind or visually impaired suffer from imbalance that is why we took into account the balance of the body to avoid any risk of falling for this way we use a verbal feedback to alert them if the body is leaning and in which direction.

IV. Discussion

The Tai Chi care exercises chosen in our work are applied for the flexibility of the joints and in order to keep the body in balance. These exercises are based on flexions and extensions gestures of the knees and elbows with conditions on the angles so that they can be easily detected in order to complete the requested exercise.

For the movements of the elbows in the four exercises and the knee flexion movements for the “Handing Ball” and “Qi pose”, the success rate is 100% for most of the people involved in our study. Most of exercises were successfully performed in the all the performed tests. The “Gong Wu” and the “Ma Bu” are more difficult than the two other gestures at the knee bending level, that is why we have a lower success rate than the other results at the beginning of the practice, but after that, all the gestures are executed correctly.

Our work is also based on audio feedback for verbal correction of gestures and giving instructions to people facing the Kinect sensor. We tried to detail as much as possible the different instructions so that the voice messages are clear for all people. For example for the position of the arms for the exercise of “Handing Ball”, the instruction is as follows: “raise the arms in front, just below the level of the elbows, and turn the palms facing you as you like you have a ball between your arms”. In some cases, the failure of blind or partially sighted people is due to the lack of flexibility in the different joints of the body, as well as the fear of making unusual movements because they are very careful in their movements since they suffer from the problem of balance to avoid the risk of falling.

There is a wide range of commercial MoCap sensors that are used, for example: Orbbec Astra, RealSense R200, ZED stereo camera, Leap Motion and Kinect sensor.

Kinect V2 has several advantages compared to alternative MoCap sensors: The latter can be used to perform complete monitoring of the skeleton as well as of several bodies simultaneously, this can allow the parallel acquisition of data from more than one person; its price is relatively low. It supports several variety of software toolboxes and languages; and it also has mature drivers, and an SDK well documented and open accessed.

The Kinect V2 has an advanced depth sensor with higher resolution, as well as the ability to track more bodies and joints per body. As a result, Kinect V2 becomes a valid alternative for clinical applications, as presented by some authors. In our tests, Kinect V2 can measure the angles between the different joints of the skeleton when they are not hidden by any object or obstacle. Therefore, the limitation since the first Kinect V1 continues to be a source of error in V2. This means that, the user must be installed facing the Kinect without any obstacle between the sensor and the body, does not exceed the recommended range (0.5 m to 4.5 m) and in uniform lighting.

In our work, the user is asked through voice messages to position themselves in the correct detection position in front of the Kinect sensor. This step helps us to correctly detect the skeleton without loss of data and calculate the angles of the joints. However, in some cases, the poor detection of the angles of the knees for the exercises “Ma Bu” and “Gong Wu” is due to the difficulty of some people to bend the knees. This is why the performance does not exceed 80% success for the tests at the beginning.

V. Conclusion

The role of physical exercise is to keep our health in good condition. That is why we have given importance to people who are visually impaired to help them work out at home with a Kinect sensor, who will receive an audio feedback message for the instructions of four poses of Tai Chi treatment to keep the joints flexible and to help them to strengthen their balance, as the blind or partially sighted people suffer also from the problem of balance. This is also of great importance during this epidemic of the covid-19 virus, since most countries have imposed the confinement and people were forced to stay at home.

However, to do an activity in front of this sensor, you must position yourself correctly so that the latter can detect the person. We used the Microsoft SDK V2.0 from Kinect to obtain the 3D coordinates of the joints that are used to calculate the distance to position persons in the right detection area, the balance of the user to avoid falling risks, and joints angle who are used for the Tai Chi treatment instruction.

The instruction of Tai Chi treatment used in this work is able to detect successfully the flexions and extensions of the knees and elbows joints for the different gestures and measure body leaning to keep it in balance.

Although this work is not intended only for blind or partially sighted people, it is accessible for any person who want to practice this treatment without looking to the screen just by receiving a useful and customized audio feedback.

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Optimized Machine Learning based Classifications of Staging in Gynecological Cancers using Feature Subset through Fused Feature Selection Process

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***Abstract*—After diagnosing the cancer, the next step is to identify the staging of the cancer to start with the appropriate treatment plans. There are different kinds of gynaecological cancers and this research lays emphasis on cervical and ovarian cancer types with their staging classifications. The cervical and ovarian cancers data from SEER registry are used in this work. This work intends to propose an optimized classification method for staging prediction in gynaecological cancers through fused feature selection process that aimed to provide an optimal feature subset. The fused feature selection process includes the hybridization of relief filter approach with wrapper method of genetic algorithm to produce revised feature subset of data as an outcome. Accordingly, this work attained an improved feature subset through fused feature selection process for precise classification of cervical and ovarian cancer stages by identifying their significant features. The predictive models are established with 10-fold cross validation using major classification algorithms like C5.0, Random Forest and KNN. The classification results are attained for the respective types of cervical, ovarian cancer stages and the stage-wise classification based on patients age also obtained through this proposed method. The results portrayed that the women in the age group of 45 and above are more critical with the incidence of cervical and ovarian cancer types. Random Forest method has shown progressive accuracy rate with progressive percentage of other performance outcomes. Also, this work recognized that the best and optimal feature subset selection could condense the complexity of the predictive model.**

Keywords*—Ovarian cancer; cervical cancer; diagnosis; gynaecological cancers; staging; feature selection; machine learning; classification

I. Introduction

Gynaecological cancer denotes five types of cancers which starts in the reproductive organs of women. Cervical cancer is a form of gynaecological cancer that originates in the cells that line the cervix. This cancer type is most identified in women between ages 35 and 44. The average age at diagnosis is 50 years. Also, there are higher chances of the patients risking the development of cervical cancer as they grow older. Ovarian cancer is a type of gynaecological cancer which is more perilous in recent times. Ovarian cancer is ranked fifth in cancer demises among women [1]. Early detection of ovarian cancer could have a huge influence on the cure rate and it is instantly needed [2], but only 20% are found at a primary stage. The study [3] to find the survival outcome in ovarian cancer patients insisted that accurate estimation is essential for the reason that prognosis could be a determining factor of medication aggressiveness. Both cervical, ovarian cancers are critical but early detection of these cancers are erratic in most of the women. After diagnosing any type of cancer, it is obligatory to identify the staging to know about how much it has affected the other organs of the body. Staging procedure helps to decide better treatment plans and to know about survival information. Thus, it is essential to identify these conferred types of gynaecological cancer stages in an accurate manner to initiate with effective treatment procedures for the patients. The sections of this paper are structured as follows. In Section 2, the literature study is discussed, Section 3 shows the types of staging classes in cervical and ovarian cancers. In Section 4, the proposed methodology for staging classifications is discussed and the implementation procedure is discussed in Section 5. The classification outcomes of cervical, ovarian cancer stages are discussed in Section 6; in Section 7, the experimental results are shown, and the conclusion is conferred in Section 8.

II. Literature Study

Machine Learning (ML) techniques are more effective in various types of cancer diagnosis and staging predictions. The study [4] to diagnose and classify the stages of an ovarian cancer used classification and clustering methods to train the cancer images with respect to the ovarian cancer stages and this work attained 94% of accuracy. This work aimed to improve the sensitivity measure. The work [5] which proposed the system for staging predictions in cervical cancer insisted that genetic algorithms are efficient in processing the huge quantities of information. But the comparative performance of classifiers is not deliberated using various performance metrics. The study [6] which used Gynecologic Cancer Society supported open dataset applied SVM technique and suggested that SVM method accomplishes better results in classifying the stages in cervical cancer. The dataset used in this work is moderately small. For staging predictions in cervical cancer, the study [7] designed CVSS dictionary learning framework by means of multi-view MR images. This work demonstrated the results of classification accuracy in identifying the stages of cervical cancer, however the accuracy is not reasonable. The comparative study [8] using various classifiers to identify the stages in cervical cancer suggested J48 as the suitable method for classifications of stages with the

SEER, "Surveillance, Epidemiology, and End Results (SEER) Program (www.seer.cancer.gov) (*Data Source*).

accuracy of 93%, still the score for sensitivity and specificity was trivial. A decision tree-based procedure applied in the study [9] used cervical cancer data from IGCS for staging classification. This method used correlation-based feature selection and C5 algorithm, the accuracy of this method is not consistent. The staging classification study which included ovarian cancer data combined the outcomes of ten feature selection methods to select the subset for eventual classification to improve the accuracy [10]. The literature study evidenced that the accuracy attained in staging classifications of cervical and ovarian cancer is not adequate. Also, the classifications of these cancer stages among women in various age groups is also mandatory to provide better treatment plans. Accordingly, a methodology has been proposed and the results are enhanced with broad staging classifications for cervical and ovarian cancers of women in various age groups.

III. Types of Staging Classes in Cervical and Ovarian Cancers

Staging is the procedure of identifying the amount of cancer in an individual's body and its setting in the body. This procedure helps to determine how severe the cervical or ovarian cancer is and deciding about the exact and best treatment for the same.

A. Cervical Cancer Staging Classes

Cervical cancer's most common staging classification is the FIGO system - International Federation of Gynaecology and Obstetrics. The cervical cancer stages are summarized in Table I.

TABLE I. Cervical Cancer Stages

FIGO Stage	Stage Description
Stage I	Cancer has spread into the deeper tissue from the cervix liner.
IA	Tumour is < 5 mm deep, and < 7 mm wide.
IA1	Tumour's depth is not > 3 mm and < 7 mm wide in tissues.
IA2	Tumour depth is >3 mm, but < 5 mm and < 7 mm wide.
IB	Tumour is in the cervix, and the size is wider than in IA2.
IB1	Tumour is not > 4 cm at its widespread part.
IB2	Tumour is not < 4 cm at its widespread part.
Stage II	Cancer has spread outside of the cervix to closer parts.
IIA	Tumour has not spread into tissues adjacent the cervix and uterus.
IIA1	Tumour is not > 4 cm at its extensive part.
IIA2	Tumour is not < 4 cm at its extensive part.
IIB	Tumour has spread adjacent to the cervix and uterus.
Stage III	Tumour has spread to the pelvis walls.
IIIA	Tumour has grown into the lower part of the vagina.
IIIB	Tumour has grown into the pelvis walls and has blocked a ureter.
IVA	Tumour has grown into the bladder, rectum.
IVB	Cancer has spread to further parts of the body.

B. Ovarian Cancer Staging Classes

The FIGO (International Federation of Gynaecology and Obstetrics) system and the AJCC (American Joint Committee on Cancer) TNM staging system are the two main systems used for classification staging in ovarian cancer. The ovarian cancer stages are shown in Table II.

TABLE II. Ovarian Cancer Stages

FIGO Stage	Stage Description
Stage I	Tumour curbed to ovaries.
IA	Tumour is limited to only one ovary.
IB	Tumour affects both the ovaries.
IC	Tumour covers one/both ovaries with subsequent consequences.
Stage II	Cancer has affected one/both ovaries, spreads to other pelvic areas.
IIA	Cancer has the extension and/or implant on uterus
IIB	Cancer has the extension to other pelvic intraperitoneal tissues.
IIC	This stage comprises IIA or IIB with positive washings/ascites.
Stage III	Tumour encompasses one/both ovaries with cytologically formed, spread to the peritoneum outside the pelvis.
IIIA	Cancer covers the pelvis only, but the cancer cells which are visible only through a microscope are spread to the out of the peritoneum.
IIIB	Cancer has moved to the peritoneum; its size is <= 2 cm.
IIIC	Cancer has moved to the peritoneum which is not < 2 cm and/or it has moved to the abdominal lymph nodes.
Stage IV	Cancer has affected the area outside the abdomen to other organs, such as the lungs or the tissue inside the liver.

IV. Proposed Methodology for Staging Classifications

It is evident through various inquiries that combined feature selection approaches are effectual in handling high dimensional data and proficient in achieving enhanced classification results [11][12]. This research aimed to provide an optimized classification method for staging predictions in cervical and ovarian cancers data with enhanced performance outcome. Consequently, a methodology is proposed here with Revised and Improved Feature Subset through Fused Feature Selection process (RIFSt_2FS) framework. The proposed methodology is depicted through Fig. 1.

After obtaining the data from the registry, the pre-processing of data is required to remove the missing values and formatting of the data. Initial feature set is generated with initial features. Inappropriate and superfluous features need to be removed to attain an effective classifier model [13]. To attain an enhanced feature subset the procedure mentioned in the RIFSt_2FS framework is implemented using Relief and Genetic Algorithm. After attaining the enhanced and revised feature subset the prominent classification algorithms in ML are applied for various types of staging classifications. The best and optimized classification approach is selected based on the evaluation of various models.

Revised and Improved Feature Subset through Fused Feature Selection process (RIFSt_2FS) framework is designed as shown in Fig. 2 which is intended at an optimal feature subset for improved prediction performance for staging classifications in gynaecological cancers.

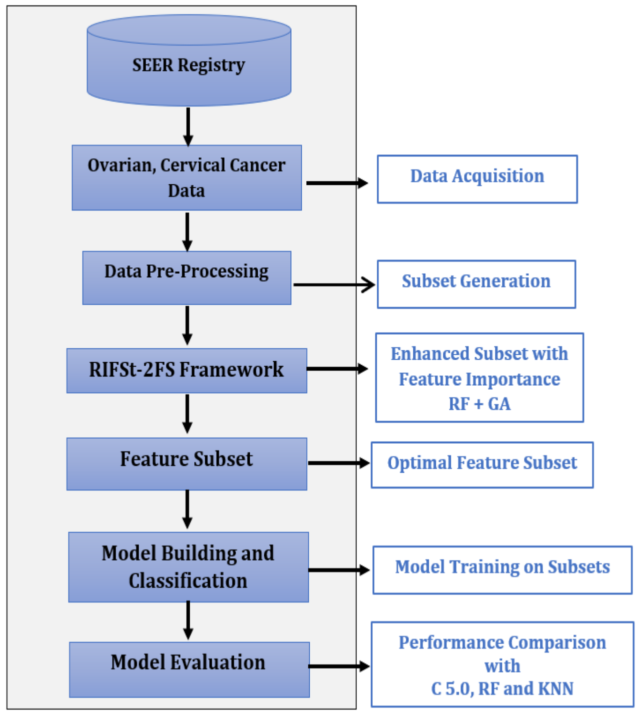

Fig. 1. Proposed Methodology for Classification of Gynaecological Cancer Stages using RIFSt_2FS Framework.

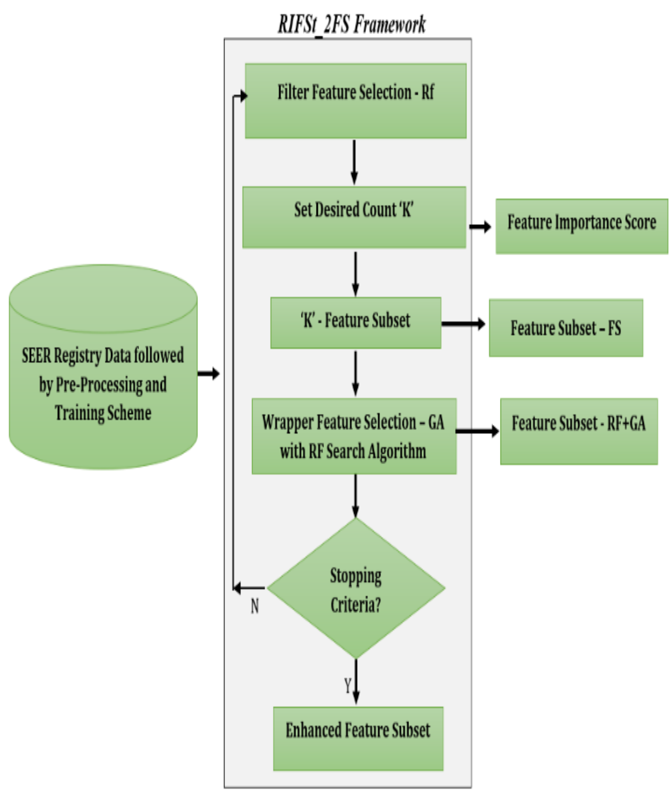

Fig. 2. RIFSt_2FS Framework.

V. Implementation of RIFSt_2FS Framework for Staging Classification in Gynaecological Cancer Data

The implementation procedures of the proposed framework for gynaecological cancer staging prediction with fused feature selection process are conferred in this section.

A. *Procedure for Classification of Cervical and Ovarian Cancer Stages with RIFSt_2FS Framework*

The illustrative procedure to implement the proposed methodology is designed and the sequence of phases in the process are as follows.

Step 1: Begin
Step 2: Select gynaecological cancer data from SEER registry using cancer type, province, and year of diagnosis
Step 3: Import dataset as .csv file from SEER registry
Step 4: Apply Data Pre-Processing
Step 5: Plot preliminary feature importance
Step 6: Prepare training scheme
Step 7: Call the procedure RIFSt_2FS (Feature Importance using Relief and Genetic Algorithm)
Step 8: Generate Feature Subset FS
Step 9: Obtain classification result for initial set of features
Repeat {

- *Train and build the models with preliminary features through repeated K-fold c.v using ML classifiers C5.0, RF and KNN*
- *Generate variable importance score*

}
Until the specified number of required models' attainment
Step 10: Train and build the models with the feature subsets generated through RIFSt_2FS with repeated K-fold c.v using ML classifiers C5.0, RF and KNN
Repeat {

- *Acquire Classification results with various stages of cervical, ovarian cancers*
- *Obtain age-wise classification of cervical, ovarian cancer stages*

}
Until the attainment of specified classifications of various cancer stages and ages
Step 11: Evaluate the performance of all the models with test data
Step 12: Designate the optimal feature subset and classification approach
Step 13. End

B. *Dataset*

The SEER [14] (Surveillance, Epidemiology, and End Results) is a database which contains largest and greatest comprehensive information on all the types of cancer incidences. This registry has the cancer patients' populations' data from America and from Asian/Pacific regions as it is the worldwide cancer data collection system. To select only relevant data, few conditions were made to decide the pertinent cases. The conditions are like region (Asian/Pacific Islander/Indian patients), cancer type as ovary (C56.9), cervical (C53.9) with confirmed diagnosis and the year of diagnosis ranged from 2000 to 2017. The selected instances were organized as CSV files.

C. Data Pre-Processing

The selected instances had some missing values for few columns. Missing values were replaced with mean or mode based on the attribute types and few rows were removed which had major number of missing values in their fields. After pre-processing, the cervical cancer dataset comprises 4062 instances and the ovarian cancer dataset had 5843 instances. The cervical and ovarian cancer data instances are segregated as training and test data for training and performance evaluation of prediction models.

D. Feature Selection

Feature selection is the vital stage in obtaining optimized prediction models with advanced classification accuracy through reduced number of features of the dataset. As our objective is to obtain reduced and an improved feature subset, we intended to apply fused feature selection process by integrating filter and wrapper methods. The pre-processed dataset had more than 30 attributes which represented various test results of the patients along with their age and marital status. The integrated approach of feature selection process aimed to reduce these attributes and thereby getting an enhanced and improved feature subset which can be used for classifying the cancer stages. The expected outcome of this phase is to obtain an optimal feature subset which contains major significant features which are essential for staging classification of cervical, ovarian cancer data.

E. Incorporation of Filter and Wrapper Feature Selection Methods

There are several methods available for feature selection processes using filter and wrapper approaches. It is evident through various researches that the Relief algorithm which uses filter approach and Genetic algorithm with wrapper approaches are more effective in gaining optimal feature subsets by assigning precise rankings and selecting relevant features of the dataset. Based on our prior findings, the filter feature selection approach of relief method is fused with wrapper approach using genetic algorithm to attain a fused performance by fabricating an optimal feature subset of mentioned cancer datasets. The phases of the fused feature selection process anticipated for the generation of the feasible combinations of improved feature subsets is described below:

1) Procedure: RIFSt_2FS – Revised and Improved Feature Subset through Fused Feature Selection Process.

The feature subset obtained through this integrated feature selection process is expected to have an enhanced and revised feature which could be used for the succeeding phase of classification of discussed gynaecological cancer stages.

Input: Cervical, Ovarian Cancer training dataset with primary features
Output: Feasible groupings of enhanced feature subsets which are ideal for staging prediction
Phase 1 - Filter Phase - Obtaining refined datasets through filter-based FS process
Determine the Number of Desired Features
Apply Relief Algorithm
Obtain Dataset (Rf) - Features nominated through Relief
Phase 2 - Wrapper Phase - Wrapper-based FS using Random Forest (RF) for the refined datasets attained in Phase 1

- *Initialise this phase with the features selected in Phase 1*
- *Repeat this phase until termination criteria of Genetic Algorithm's*

Dataset obtained from phase 1 (Rf) applied to wrapper approach with Genetic Algorithm (GA) by assessing the fitness with Random Forest (RF) to accomplish a compact feature subset as Rf_GA.

F. Gynaecological Cancer Stages Classification with K-Fold Cross Validation

For classifying all the stages of cervical and ovarian cancers, prominent ML classification algorithms are executed on the datasets accomplished with optimal features. Repeated K-fold cross validation technique is recommended for model training and in the process of building various classifiers through ML classification algorithms for determining an optimized classification technique [15]. The prevalent classification algorithms used for model training and validation are Random Forest, C5.0 and K-Nearest Neighbor. The classifier models are initially constructed with conferred ML algorithms using all the preliminary features and with the feature subset gained through fused feature selection process by combing Relief and Genetic Algorithm. The classification results are conferred under Results Section with detailed analysis of stagewise and age-wise groupings.

G. Performance Evaluation

The performance of the predictive models obtained through ML classification algorithms are assessed based on performance metrics accuracy. Initially, the predictive performance of algorithms such as Random Forest, C5.0 and K-Nearest Neighbour are evaluated on training datasets with preliminary features by means of applying test data for validation. Subsequently the model generated through fused feature selection process is assessed by means of test data with the stated classification algorithms based on their proficiency in classifying the data to the appropriate cervical, ovarian cancer stages. The performance metrics used in this work s accuracy, which is calculated as shown below.

Accuracy = (Total No. of correct predictions)/(Total No. of instances)

The optimal feature subset generated through RIFSt_2FS method is effectual for appropriate staging classifications of cervical, ovarian cancer with extreme accuracy and improved performance outcomes. This approach has shown prominent results as compared with the existing techniques with image classifications [16], [17] The outcomes are conferred in the subsequent section.

VI. Discussion

The proposed framework is efficient in identifying the important and relevant features which are to be designated for cervical and ovarian cancer staging classifications.

A. Variable Importance

The significant features derived through RIFSt_2FS method are termed as an optimal feature subset for staging classification of gynaecological cancers data. The overall variable importance in cervical and ovarian staging classifications is obtained and the chart of C5.0 method for combined staging prediction in ovarian cancer is depicted in Fig. 3.

B. Classification of Cervical and Ovarian Cancers Test Data

Based on the dataset retrieved from SEER Registry, we were able to predict the stages for 1078 cervical cancer patients and 1446 ovarian cancer patients which are specified as test data in this work. This work aimed to classify the stages of cervical and ovarian cancers with their sub types and through the patients' age-wise aspects through each stage of cervical and ovarian cancers.

1) Comprehensive Stagewise Classification Results of Cervical and Ovarian Cancers. The inclusive classification of all the stages of cervical cancer is shown in Table III and Fig. 4. It is obvious through the results that incidence of Stage IIIB and Stage IB1 cervical cancer are higher and Stages III and IV are considered as more critical.

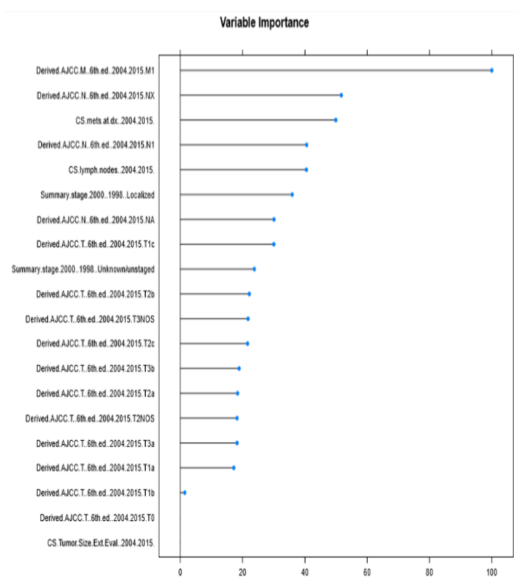

Fig. 3. Variable Importance in C5.0 Algorithm for all the Stages of Ovarian Cancer.

TABLE III. Classification of Stage I to Iv of Cervical Cancer using RIFSt_2FS Framework

STAGES	Type	Patients	Percentage
STAGE I N=489, Ratio=45.36	IA	6	0.56
	IA1	144	13.36
	IA2	45	4.17
	IB	27	2.50
	IB1	207	19.20
	IB2	60	5.57
STAGE II N=177, Ratio=16.42	IIA	51	4.73
	IIB	126	11.69
STAGE III N=254, Ratio=23.56	IIIA	16	1.48
	IIIB	238	22.08
STAGE IV N=158, Ratio=14.66	IVA	17	1.58
	IVB	141	13.08

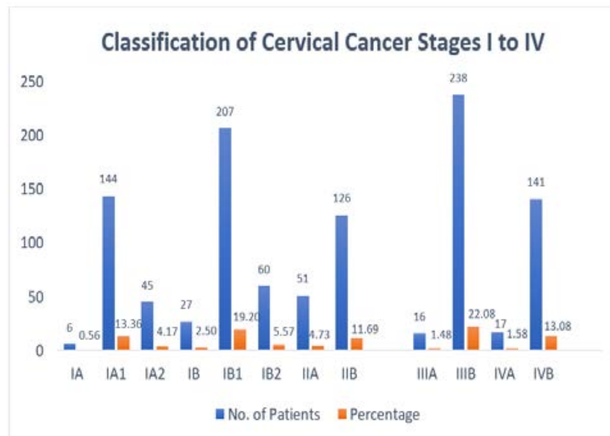

Fig. 4. Classification of Stage I to IV of Cervical Cancer using RIFSt_2FS Framework.

In a similar way, the inclusive classification of all the stages of ovarian cancer is shown in Table IV and Fig. 5. It is obvious through the results that incidence of Stage IIIC and Stage IV ovarian cancers are higher besides considered as more critical. The study [18] to know the implication among diagnostic patterns and stages in ovarian cancer using medical indicative features and symptoms insisted that self-attention is vital for all women.

2) Age-Wise Classification Aspects with Specific Stages of Cervical and Ovarian Cancer. The comprehensive classification of all the stages of cervical cancer based on the age groups is depicted in Fig. 6. It is obvious through the outcomes that the women in the age group 35-44 and 45-54 are more critical to be affected with all the types of cervical cancer stages of 1 to 4. The stages IB1 and IIIB is higher. The women in the age group 35-44 are also having more percentage of occurrences in the stages IA1, IB1 and IIIB. So consistent follow-up and timely treatment could diminish the critical and life-threatening situations for those women. Consecutively, the comprehensive classification of all the stages of ovarian cancer based on the age groups is depicted in Fig. 7.

TABLE IV. CLASSIFICATION OF STAGE I TO IV OF OVARIAN CANCER USING RIFST_2FS FRAMEWORK

STAGES	Type	Patients	Percentage
STAGE I N=490, Ratio=33.88	IA	272	18.81
	IB	13	0.89
	IC	205	14.18
STAGE II N=145, Ratio=10.03	IIA	30	2.07
	IIB	63	4.36
	IIC	52	3.6
STAGE III N=417, Ratio=28.84	IIIA	27	1.87
	IIIB	37	2.56
	IIIC	353	24.41
STAGE IV N=394, Ratio=27.25	IV	394	27.25

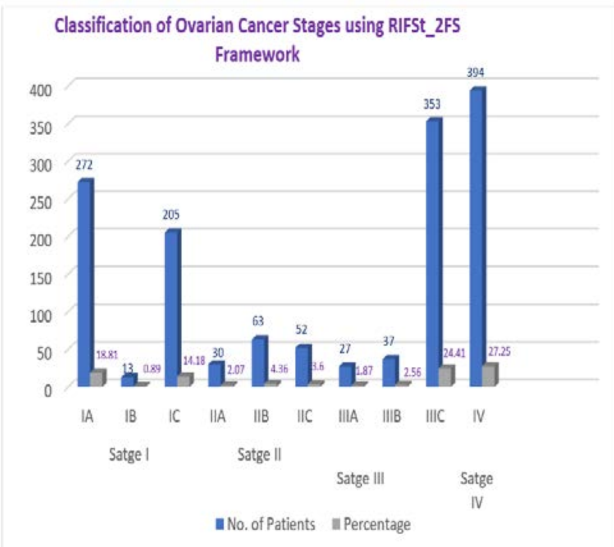

Fig. 5. Classification of Stage I to IV of Ovarian Cancer using RIFSt_2FS Framework.

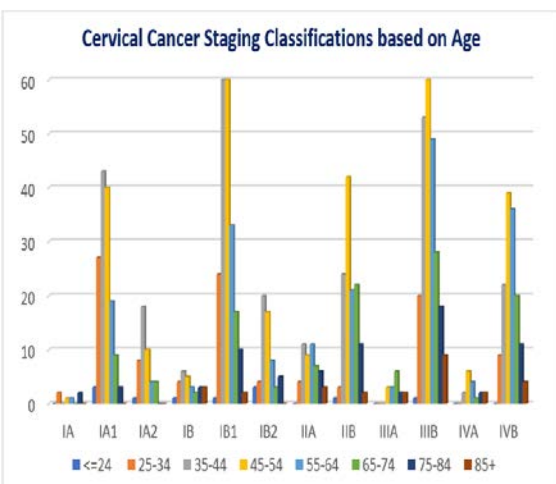

Fig. 6. Classification of Cervical Cancer Stages I to IV based on Age.

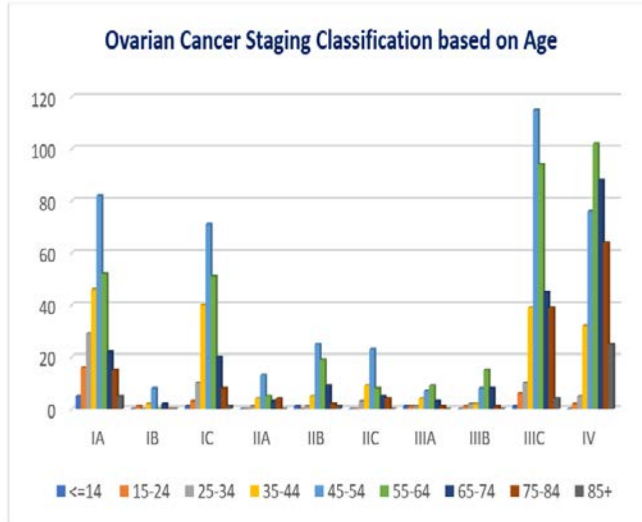

Fig. 7. Classification of Ovarian Cancer Stages I to IV through Age.

It is apparent through the findings that the women in the age group 45-54 are more critical to be affected with all the types of ovarian cancer stages of 1 to 4. The women in the age group 55 and above are more affected with stage 4. Correspondingly, this classification shows that the ovarian cancer stage IIIC is having more incidence in the women with age group 45-54.

VII. RESULTS

Random Forest and C5.0 classifiers have tremendously performed well in categorizing all the stages of cervical and ovarian cancer types using RIFSt_2FS Framework with precise results. The results proved that RF and C5.0 are the finest classifiers and the results attained through KNN are not satisfactory. Consequently, we have attained an optimized classification results using Random Forest classifier. The performance results of the classifiers are shown in Table V and Fig. 8.

The performance of proposed approach with RF classifier is aggregated and compared with some of the existing studies and the findings are shown in Table VI and Fig. 9.

TABLE V. PERFORMANCE OF ML CLASSIFIERS IN CERVICAL AND OVARIAN CANCER STAGING CLASSIFICATIONS

ML Classifiers with Performance Measure		**Accuracy**		
		C5.0	**RF**	**KNN**
Cervical Cancer Staging Types	Stage I	97.4	97.6	93.9
	Stage II	95.2	96.3	87.6
	Stage III	96.4	96.8	83.5
	Stage IV	97.2	97.2	89.2
Ovarian Cancer Staging Types	Stage I	97.6	97.6	91.8
	Stage II	95.9	97.3	86.9
	Stage III	97.3	97.5	85.4
	Stage IV	97.2	97.2	88.6

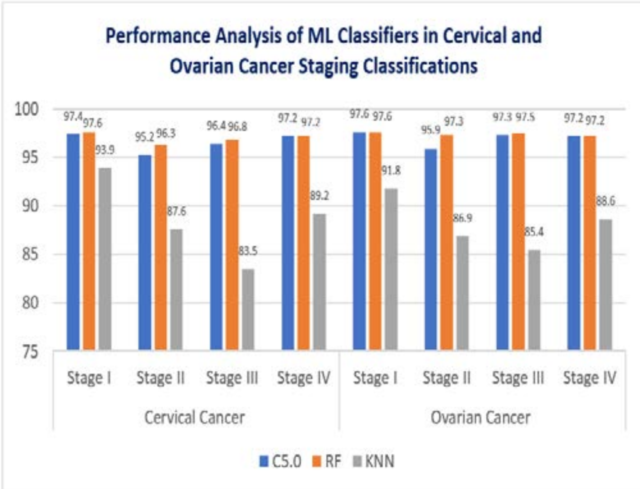

Fig. 8. Performance Analysis of ML Classifiers in Cervical and Ovarian Cancer Staging Classifications.

TABLE VI. PERFORMANCE ANALYSIS OF PROPOSED APPROACH RIFST-2FS

Staging Classification	Research Studies	Accuracy (%)
Cervical Cancer	D. S. Latha et al. [8]	93
	J. Singh and S. Sharma [19]	78
	S. Sunny and G. Sandeep [20]	85.65
	Proposed Approach (**RIFSt_2FS**)	**96.98**
Ovarian Cancer	A. Sidhant and L. Sehgal [4]	94
	R. Chen et al. [21]	76.1
	A. El-Nabawy et al. [22]	80
	Proposed Approach (**RIFSt_2FS**)	**97.4**

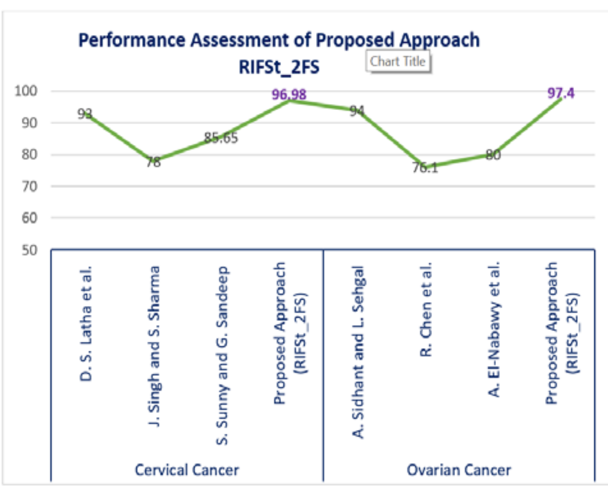

Fig. 9. Performance Assessment of Proposed Approach RIFSt_2FS.

VIII. CONCLUSION AND FUTURE WORK

This work is intended to attain for an improved feature subset through fused feature selection process for precise classification of cervical and ovarian cancer stages by identifying the significant features. The integration of feature selection methods through fused approach enhances the performance of staging classifications through its positive, negative predicted values of the results with uppermost accuracy and improved performance measures. The predictive models are established with 10-fold cross validation using major classification algorithms like C5.0, Random Forest and KNN procedures. The classification results are attained for the respective types of cervical and ovarian cancer stages and the stage-wise classification based on patients age also obtained through this proposed method.

This proposed method has shown improved performance outcomes than the studies discussed in the literature. The results portrayed that the women in the age group of 45 and above more critical with the incidence of cervical and ovarian cancer types. It is mandatory for all the women to have a regular follow-up and timely treatments to reduce the complications in the advanced stages. Random Forest method has shown progressive accuracy rate with 97 percentage of combined performance outcomes. C5.0 algorithms has also shown improved accuracy in all the types of staging classifications of cervical and ovarian cancers. But the performance of KNN algorithm is comparatively less than RF and C5.0 methods. The experiments revealed that through enactment of fused feature selection approach an optimal and reduced feature subset is appropriate for the improvement of classification accuracy with a reduced computational cost. Also, this work recognized that the best and optimal feature subset selection could condense the complexity of the predictive model.

In future work, the staging classifications for other types of gynaecological cancers like uterine, vaginal, vulvar cancers will be analyzed using further types of ML classifiers with other performance metrics like sensitivity, specificity, precision, and F-score values.

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DECLARATION

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A Systematic Review on Practical Considerations, Recent Advances and Research Challenges in Underwater Optical Wireless Communication

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***Abstract*—Underwater Optical Wireless Communication (UOWC) has gained significant attraction in many underwater activities because of its high bandwidth as compared to radio frequency and acoustic technologies. Underwater Optical Wireless Communication (UOWC) has high stature in underwater observation, exploration and monitoring applications. However, due to complex nature of ocean water, several practical challenges exist in deployment of UOWC links. Qualitative and effective research has been carried out in UOWCs from last few decades. Ambition behind this research systematic study is to provide a comprehensive survey on latest research in UOWCs. Herein, we provide a brief discussion on major research challenges, limitations and development in UOWCs. We provide a periodical review on UOWC issues and potential challenges highlighted in previous studies. In this paper, we have also investigated research methods to gain attention of research fraternity towards future technologies and challenges on the basis of existing approaches. Thus, it is our foremost requirement to provide state-of-the-art analysis of existing UOWCs. Significant deliberation has been provided with recent bibliography.**

Keywords*—Component; underwater optical wireless communication; underwater technologies; research questions; 5G/6G

I. Introduction

An extensive research has been carried out on free space optical wireless communications in different aspects and nowadays Underwater Optical Wireless Communication (UOWC) is generating considerable attention among recent researchers. UOWC is an emerging technology for premier research in underwater environment. It is a fusion of optical and wireless technologies having intelligent computing, smart sensing and communication abilities. UOWC is used in numerous applications such as mineral exploration, ocean observation, submarine communication, diver-to-diver communication, military applications, underwater navigation and surveillance. UOWC has successfully proven its stature in target detection, objection tracking, underwater robotics, monitoring, AUVs communication and oceanographic data transmission and collection. Though UOWC is providing cutting-edge solutions but many challenges exist at the same time. The researchers face challenges regarding link deployment, propagation delay, high bit error rates, Doppler spread, connectivity losses, attenuation, scattering, turbulence, low bandwidth, high latency, multipath propagation and salinity. The unpredictable condition of ocean environment generates these serious challenges and issues in designing and deployment of UOWC links. In this paper, we have investigated several challenges and presented our work summary on it. We have discussed several constraints and particularities in this systematic review. We have briefly discussed the feasible countermeasures to tackle these challenges in existing UOWC mechanism. UOWCs are vulnerable to numerous factors such as scattering, absorption and fading. In addition, UOWC performance is limited to short range [1] and extensive research is required for long range communications. Researchers are working to design systems and methodologies to transmit broadband optical signals at larger distances. In near future, submarine optical communication systems will be available commercially [2]. A general UOWC system is displayed in Fig. 1. It shows that different underwater platforms such as submarine, sensors, ships and divers are connected through light beams.

An extensive research is being carried out to develop a complementary technology which can allow broadband underwater communications such as real-time video transmissions, tele-operation of AUVs and remote monitoring of underwater stations [4]. In future, optical communication will be used for many underwater applications. However, UOWC cannot fully replace acoustic communications. For this purpose, scientists are focusing on hybrid optic/acoustic communications [5].

We have briefly discussed several potential features in our systematic review. We have included modulation schemes, channel coding, UOWC challenges and OWC revolution in

5G and 6G networks. We have organized this paper as shown in Fig. 2.

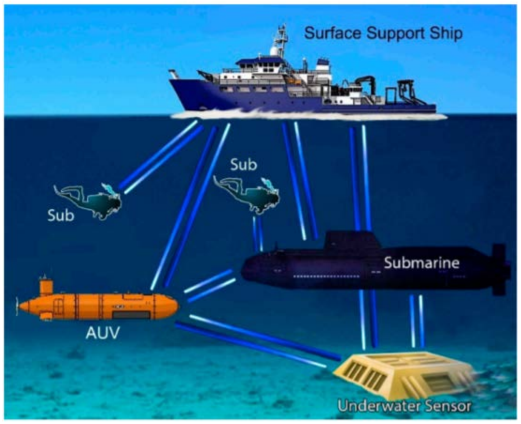

Fig. 1. UOWC System [3].

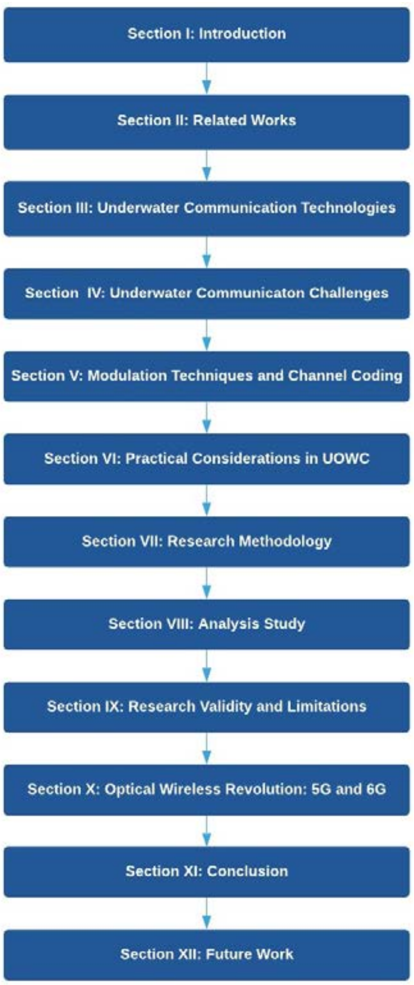

Fig. 2. Overview of Reseach Work.

II. Related Work

In this section, we have summarized practical considerations and issues in UOWCs in existing research literature. We provide an overview of UOWC technology, enhancing functions and issues highlighted in recent research publications. Previous researchers have provided scholarly discussions about communication technologies, technical aspects and challenges of UOWC. In a recent research study conducted in 2020 [6], researchers have provided a review on practical consideration and solution in UWOCs. They have addressed underwater challenges and possible solutions. They have discussed misalignment in underwater links and highlighted novel solutions to bring robustness in UWOC links. An exhaustive and inclusive survey of state-of-the-art UOWC is given in which authors have considered aspects of coding techniques, modulation and channel characterization [7] in UOWCs. A good scholarly approach based on overview of current advances in UOWC is given in an article [8]. In this study, authors have focused the reliability and feasibility of optical links with higher data rates. Emerging optical wireless communications, transcutaneous OWCs, optical scattering and free space optics are discussed in a previous study [9]. Khalighi et al. [10] have given a performance study of typical UOWC system and addressed open issues. Performance of FSO systems and various impairments which degrade FSO performance are highlighted in [11]. Authors have discussed FSO modulation, coding schemes using various detection techniques. In a Master's thesis, Z. Zeng has given an interesting survey about optical wireless communications [12]. Author has provided good remarks for UWOC channel modeling, channel modulation and coding techniques. Weihao Liu et al. provided a roadmap to characterize an UOWC channel with considering both underwater optical turbulence and absorption/scattering [13]. Pal A. van Walree carefully addressed scattering, propagation and fading effects [14]. Researchers have conducted a brief survey on recent advances, research activities and potential applications [15] of OWC. Aobo Lin et al. [16] successfully demonstrated UOWC by carrying out experiments with blue LEDs. A blue GaN-based micro-LED was used to achieve high speed in UOWC [17]. An efficient diver-to-diver communication system was demonstrated in [18], researchers claimed to transmit audio signal by using LEDs of different wavelengths. Peppas et al. [19] have discussed performance of UOWC systems and investigated effects of oceanic turbulence and inter-symbol interference. Rashed et al. [20] have constructed an underwater link budget for realistic ocean water by considering scattering and absorption. Depth dependent variation in attenuation and beam refraction are addressed by LJ Johnson [21-22]. He also outlined transmission characteristics for UOWC in [23]. A concise review on UOWCs and hidden abilities of optical spectrum is addressed [24]. Authors in [25] performed experimental trials to check optimum LED wavelengths for UOWCs. Opportunities and challenges in OWC technologies are highlighted in a study [26]. The effects of collimated laser beams in UOWC links are investigated [27]. D. Anguita et al. have proposed a UOWC model for AUVs [28]. Optical amplification and spatial diversity for UOWC is discussed in a previous study [29]. Johnson et al. have focused on the impact of link orientation in UOWC [30]. UOWC system for real time swimmers is designed by some researchers [31]. They have also addressed air bubbles effect in their study. Table I summarizes the research work and key aspects in different years.

TABLE I. RESEARCH WORK

Reference #	Focused Key Areas	Year
[32]	OWC for UWSNs	2010
[28]	UOWC applications	2011
[31]	Real time application of UOWC	2012
[20]	Underwater link budget	2013
[21]	Attenuation in water	2013
[10]	UOWC recent dancesandcllnges	2014
[22]	Beam refraction in water	2014
[23]	Transmission characterictis in UOWC	2014
[30]	Link orientation in UOWC	2014
[9]	OWC advances and challenges	2015
[13]	Turbulence effect and detection schemes for UWOC	2015
[15]	Recent advances and potential applications	2015
[7]	Link misalignment issues	2016
[29]	Optical amplification and spatial diversity	2016
[19]	Oceanic turbulence effect and ISI	2017
[26]	Opportunities and challenges	2017
[33]	Turbulence effect on UOWC	2018
[13]	Research challenges and roadmaps for UWOC	2019
[6]	Practical considerations and solution for UOWC	2020
[3]	Comparative analysis of UWOC	2020

III. UNDERWATER COMMUNICATION TECHNOLOGIES

Current underwater optical systems consider acoustic waves as EM waves cannot travel properly. However, acoustic waves have limitation in aspects of limited bandwidth and slow speed. Acoustic communication is preferred for long distance but optical communication gives better performance for short distance. Light signals lose energy and change direction due to water particles. These challenging factors limit the range of communication system.

Table II presents characteristics comparison between existing underwater wireless technologies.

We have plotted a performance comparison of the four channels by considering their data rate and transmission range in MATLAB as shown in Fig. 3.

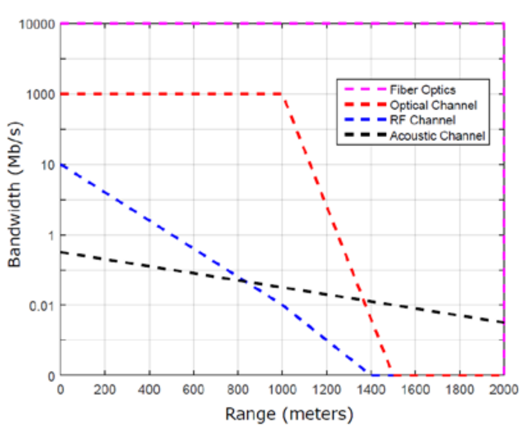

Fig. 3. Transmission Channels.

TABLE II. CHARACTERISTICS OF UNDERWATER TECHNOLOGIES

Characteristics	Optical	Acoustic	Radio Frequency
Performance Parameter	Scattering, Absorption	Pressure, Salinity and Temperature	Permitivitty, Permeability and Conductivity [38,39]
Transmission Power	Few Watts	Tens of Watts	mW to hundreds of Watts
Bandwidth	10-150 MHz	1000 km < 1kHz and 1-10 km ≈ 10 kHz and <100m ≈ 100 kHz	MHz
Latency	Low	High	Medium
Attenuation	0.39 dB/m Ocean	0.1-4 dB/km	3.5 - 5 dB/m
Size of Antenna	0.1 m	0.1 m	-
Data Rate	Gbps	kbps	mbps
Efficiency	30 kbits/Joules	100 bits/Joules	
Speed	2.2×10^8	1500 m/s	2.2×10^8
Frequency Band	10^{12}-10^{15} Hz	10-15 kHz	20-300 Hz (ELF)
Distance	10-100 m	Up to kms	Up to 10 m

Table III summarizes the benefits and limitations of different technologies implemented to achieve UWC.

TABLE III. COMPARISON OF UNDERWATER TECHNOLOGIES

UWC Technologies	Limitations	Benefits
Optical	– Severe scattering and absorption – Difficulty to cross air/water interface – Medium range	– Low cost – Lightweight – High data rate – Immune to latency
Radio Frequency	– Costly – Bulky – More energy consumption – Short range	– Tolerant to turbidity – Moderate data rate – Smoth flow from air/water interface
Acoustic	– High latency – More energy consumption – Costly – Dangerous for marine species – Low data rate	– Long distance communication – Widely used UWC technology

IV. UNDERWATER COMMUNICATION CHALLENGES

In this section, we have briefly discussed different potential challenges which degrade the performance of UOWC system.

A. Scattering and Absorption Issues

In optical region, waves are highly faded due to scattering and absorption. The extinction coefficient c of water medium is the attenuated beam over the complete path length. Extinction coefficient is the transmission wavelength which minimizes the propagation loss and it varies for different types of water. It is obtained by adding both absorption and scattering coefficients [34] a and b.

$$c(\lambda) = a(\lambda) + b(\lambda) \quad (1)$$

Table IV shows the color frequencies and respective wavelengths. Different color lights get absorbed at different water levels, where every water level has related spectrum characteristics.

Fig. 4 illustrates the absorption coefficient of pure seawater for different transmission wavelengths.

Extinction coefficient across a wide range of wavelengths in water is shown in Fig. 5. It can be concluded that blue light is useful for open ocean operations.

Table V provides the scattering, absorption, and extinction coefficient for different types of types of waters. Thus, we conclude demonstrating a UOCS closer to shore is more challenging than wide open ocean.

B. Attenuation

In water, less attenuation appears in wavelengths corresponding to blue green spectrum. However, optical link is associated to optical properties of the water and it varies according to geographic location. Attenuation (dB/m) variation against different wavelength ranges is shown in Fig. 6.

TABLE IV. LIGHT COLORS CHARACTERISTICS

Colour	Frequency	Wavelength
Red	400-484 THz	620-750 nm
Orange	484-508 THz	590-620 nm
Yellow	508-526 THz	570-590 nm
Blue	631-668 THz	450-475 nm
Green	526-606 THz	495-570 nm

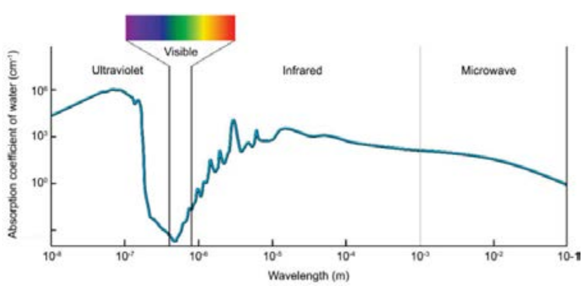

Fig. 4. Absorption Coefficient of Pure Water [3].

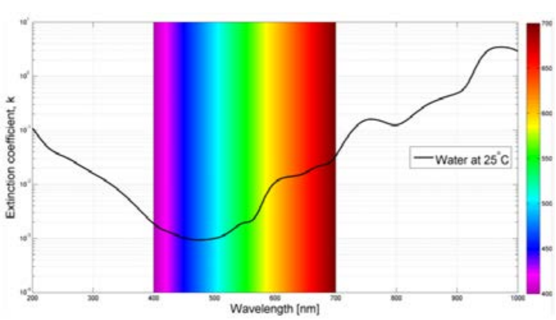

Fig. 5. Extinction Coefficient Variation [34].

TABLE V. OPTICAL PROPERTIES OF OCEAN WATER TYPES

Water Type	a (m-1)	b (m-1)	c (m-1)	-10 dB distance (m)
Fresh Water	0.040	0.02	0.042	53.55
Sea Water	0.114	0.036	0.150	15.25
Coastal Water	0.178	0.220	0.398	5.77
Harbour Water	0.366	1.828	2.194	1.05

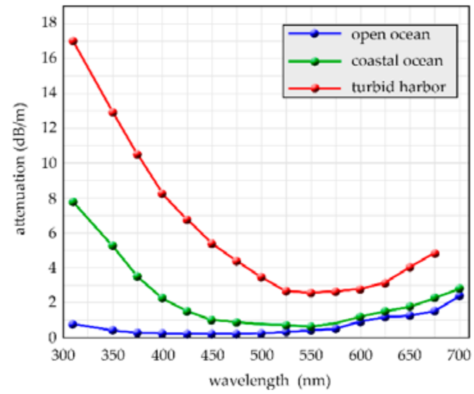

Fig. 6. Attenuation for different Waters [3].

C. Underwater Link Alignment Issue

Misalignment in optical transceivers can cause temporary disconnection in underwater optical links. Different UOWC systems make use of blue-green LEDs and lasers due to narrow divergence. However, it still requires a precise alignment [35]. A frequent misalignment is noticed at shallow depths; especially it occurs in applications based on vertical surface-to-bottom communication [21], [36]. Connection loss problem [37] occurs in case of random movements of sea surface.

D. UOWC Devices

Implementation and integration of UOWC systems needs appropriate and reliable underwater devices. Underwater characteristics such as pressure, salinity, flow and temperature highly influence the system performance and have strong impact on lifetime of UOWC devices. Energy efficient performance of whole UOWC system and reliability and sustainability of devices batteries is critical. Scholars should focus to design devices with low power consumption and higher lifetime.

V. MODULATION TECHNIQUES AND CHANNEL CODING

Modulation schemes and coding techniques are discussed in this section. UOWC is referred as FSO communication in water, conventional FSO modulation techniques can be used in UOWC systems. PWM, OOK, DPIM and PPM are the most common intensity modulation techniques. OOK is the simplest scheme having low bandwidth efficiency. The selection of modulation schemes needs inclusive knowledge and in depth understanding application framework. OOK is preferred for discrete underwater sensor nodes as it is cost effective and simple. However, more than one modulation schemes are integrated to enhance the reliability and efficiency of UOWC system. Table VI gives performance comparison of different modulation schemes.

Different channel coding techniques are required to obtain low BER in UOWC system as it suffers from severe attenuation. Channel coding has benefits of low complexity, low implementation cost, error correction capability and low energy consumption. Thus, channel coding is appropriate for compact underwater sensors operating at high SNR in underwater environment. In order to enhance robustness, channel coding techniques such as Turbo and LDPC are integrated in main data processing node of UWSNs. We have summarized different coding techniques in Table VII.

TABLE VI. UOWC MODULATION SCHEMES

Modulation Scheme	Limitation	Benefit
OOK	Low energy efficient	Low cost, Simple
SIM	Complicated devices, Average power efficiency	Low cost, Icrease system capacity
QAM	High cost, Complex implementation	Good response to noise, High spectral efficiency
PPM	Complex transceiver, Low bandwidth	High power efficiency
PoISK	Low data rate, Short distance range	High tolerance to turbulence
PSK	High cost, Complex implementation	High receiver sensitivity
DPIM	Complicated demodulation devices, Error spread in demodulation	High bandwidth efficiency

TABLE VII. CHANNEL CODING TECHNIQUES

Channel Coding	Limitation	Benefit
Turbo	Complex encoder and decoder	High error correction
LDPC	Complex encoder and decoder	High error correction
CRC	Low error correction in low SNR condition	Simple error detection codes
RS	Low error correction in low SNR condition	Robust and simple encoder and decoder
I.T	Complicated system implementation	Minimize packet loss
BCH	Low error correction in low SNR condition	Robust and simple encoder and decoder

VI. PRACTICAL CONSIDERATIONS IN UOWC

In past few years, considerable research interest has been given to UOWC but anomalies exist due to several challenges. In this section we have provided some future directions in UOWCs.

A. Channel Modeling

Researchers have designed simulation tools and close-to-reality models for horizontal links but vertical links still need attention from research community. Another practical consideration is to resolve turbulence effect in UOWC. Though turbulence is not considerable in deep waters but it must be taken into account in shallow waters. A lack in channel modeling techniques exist which should deal accurately with turbulence. The difficulty in designing such models lies in the fact that turbulence is closely related to water conditions and operating scenarios.

B. Efficient Transmission Techniques

Another essential issue to be explored is to design an opposite signaling scheme for aquatic channel. Up to now, several coding and modulation techniques are involved in UOWC systems. An improved reliability and link performance can be obtained by considering underwater channel particularities in designing of these transmission schemes. Energy efficient modulation schemes are needed for data transmission in high turbid water and powerful channel coding is required at different layers including physical and data link.

C. Mitigating Link Misalignment

A major issue in underwater environment is power consumption. One solution is to reduce the intensity loss by minimizing the beam divergence. In such scenario, energy efficient techniques and solutions are crucially important for Tx/Rx beam alignment and localization. These issues can be mitigated through designing smart Tx/Rx and adding additional components like collimating lens in UOWCs. There are some challenging issues to implement end-to-end communication links, researchers need to investigate routing protocols and spatial diversity techniques. A common UOWC system with point-to-point link needs strict tracking and pointing mechanism especially in mobility scenario. Electronic beam steering and segmented FOV can solve the issue of tracking and pointing for narrow optical beams.

VII. RESEARCH METHODOLOGY

In this section, we discuss the subject's selection process of our findings and presented the framework and approaches we used to identify our results.

A. Approaches Selection

Our investigation starts with selecting the research articles providing a survey or review on challenges in UOWCs. In order to find initial list of target research articles, we used Google Scholar search. Google Scholar helped us to obtain relevant research articles, peer-reviewed publications, abstracts, preprints and research surveys and technical reports. Google Scholar gave us confidence to complete results based on articles collected from Google search, ResearchGate and academic publishers such as IEEE, Springer and ACM. It is worth noting that Google Scholar gives full-text search against our keywords and validates that obtained research articles are relevant to our performed queries. It gives convenience by giving direct access to download research papers from relevant databases. To achieve significant coverage of research work related to UOWCs, we performed several queries on Google Scholar. First we search challenges in UOWCs, later we checked while combining research survey, review study, new trends, recent advances and limitations. We collected research articles and considered only those published in recent years in order to maintain good results and state-of-the-art approach. Basically, we selected the recent research articles related to current challenges, new trends and issues in UOWCs. We made lists of relevant papers focusing same potential features and started reading abstracts and conclusions to achieve primary study related to this review. Our research methodology includes research questions, sources and keywords. A basic overview of our research procedure is displayed in Fig. 7.

B. Research Questions

We have composed a set of research questions (RQs) and motivation behind it. These questions will be helpful for researchers to recognize the research lack in this field. RQs and motivation is highlighted in Table VIII.

RQ1. Find out the theoretical properties of UOWCs in existing and future technologies and communication devices?

RQ2. Find out good simulations tools, best architecture design, suitable modulation technique, channel modeling scheme and proper communication model?

RQ3. Find out research investigations to mitigate effects which degrade the performance of UOWC system?

RQ4. What are the potential challenges and expected link damages and connectivity losses?

RQ4. How to recover delay in case of temporary communication loss?

RQ5. Compute a complete performance evaluation for different transmission ranges and water types to meet real world requirements?

RQ6. Test each solution against possible challenges in real world environment to achieve required performance of designed UOWC system?

C. Search Strategy

We have defined a good research strategy which will be helpful for researchers to retrieve specific research literature. Our research strategy includes research method, various search terms and different data resources. Our search strategy starts with fundamental steps to identify search terms and data resources:

1) Prefatory search to retrieve previous relevant literature.

2) Check research papers published in good journals and leading conferences.

3) Consult with researchers to find relevant data from conferences and journals.

4) Trial search based on prior defined research questions.

5) Using own learning and experience related to UOWCs.

D. Search Method

In our search strategies, we used two search methods: initial manual search and later automatic search. For manual search, we selected research papers which were published in specific venues as listed in Table IX.

For automatic data search, we used electronic data resources provided in Table X to obtain relevant papers.

E. Search Terms

We used search terms related to keywords, paper titles and abstracts found in differed electronic databases. Keywords are given in Table XI. We used below provided strategies to achieve the most relevant data by forming relevant search terms.

1) Find key terms according to research questions and study topic.

2) Make list of keywords mentioned in most relevant articles.

3) Search synonyms and major term.

4) Use Boolean operator "AND" in main terms.

5) Use Boolean operator "OR" in synonyms and corresponding terms.

Fig. 7. Research Overview.

TABLE VIII. RESEARCH QUESTIONS

Research Questions	Motivation
RQ1	It will help to find out current and future advancement in UOWC
RQ2	It will help to understand complete designing process of UOWCs
RQ3	It will help to investigate factors which degrade performance of UOWC system.
RQ4	It will help to recover communication and handle delay issue
RQ5	It will help to shape the model to meet required performance criteria.
RQ6	It will help to design system with real world applications.

TABLE IX. RESEARCH KEYWORDS

Journal/ Conference	Venue	Acronym
J1	Chinese Optics Letter	COL
J2	Journal of Applied Physics	J APPL PHY
J3	Journal of Lightware Technology	J LIGHTWAVE TECHNOL
J4	Journal of Communication and Information Systems	JCIS
J5	IEEE Access	IEEE Access
J6	IEEE Communications Surveys and Tutorials	IEEE Commun. Surv
J7	IEEE Journal of Oceanic Engineering	IEEE J OCEANIC ENG
J8	Journal of Sensors	J. Sens.
J9	Photonics research	Photonics Res.
J10	Optics communications	Opt. Commun.
J11	IEEE Journal on Selected Areas in Communications	IEEE J SEL AREA COMM
J12	IEEE photonics journal	IEEE Photonics J.
C1	INTERNATIONAL CONFERENCE ON INFORMATION, COMMUNICATION AND NETWORK	ICICN
C2	International Conference on Transparent Optical Networks	ICTON
C3	International Conference on Optical Communications and Networks	ICOCN
C4	Australasian Symposium on Parallel and Distributed Computing	AusPDC
C5	International Conference on Advanced Infocomm Technology	ICAIT
C6	International Conference on Imaging, Signal Processing and Communication	ICISPC
C7	International Conference on Communications and Mobile Computing	ICCMC

TABLE X. ELECTRONIC DATABASES

Electronic Database	Search Items	Web Address
Google Scholar	Keywords, Paper Title	https://scholar.google.com/
ScienceDirect	keywords,Paper title, abstract	https://www.sciencedirect.com/
IEEE eXplore	keywords,Paper title, abstract	www.ieeexplore.ieee.org
ResearchGate	Keywords, Paper Title, Author	https://www.researchgate.net/
Sci-Hub	Keywords, Paper Title	https://sci-hub.tw/
ACM Digital Library	Keywords, Paper Title	http://portal.acm.org
Elsevier	keywords,Paper title, abstract	https://www.elsevier.com/en-au
ISI Web of Science	keywords,Paper title, abstract	http://www.webofknowledge.com
SpringerLink	Keywords, Paper Title	http://www.springerlink.com

TABLE XI. RESEARCH KEYWORDS

Keywords	Synonyms
OWCs	Optical Wireless Communications
UWC	Underwater Wireless Communication
FSO	Free Space Optics
UOC	Underwater Optical Communication
AUV	Autonomous Underwater Vehicles
UOWC	Underwater Optical Wireless Communication
UOWC Link	Underwater Optical Wireless Communication Link, Link Budget, Link Configuration
UOWC Challenges	Underwater Optical Wireless Communication Issues, Threats, Security Attacks
UOWC Survey	Review, Overview and Study on UOWC

We defined inclusion and exclusion criteria to rectify this primary study to validate our research queries.

Inclusion Criteria:

- Any paper which declares its key findings related to challenges in UOWCs.
- Any paper which is published in 2010 or after 2010.
- Any paper which is written in English language only.

Exclusion Criteria:

- Article which do not meet specific required details against our approach.
- Articles which do not contain complete information about our desired research work.
- Articles which are extended by another article that we have selected already in our list. It gives us to find representative article towards our approach.
- Articles representing short paper, only abstract, an editorial, poster summary, panel summary or workshop summary. Such articles are missing with sufficient informative data.
- Articles such as white papers and technical reports as some research communities do not rectify such articles.

In short, our primary study must provide the right approach towards UOWCs with a strong focus on emerging trends, challenging issues, opportunities and limitations. After applying inclusion and exclusion criteria, we were able to find N=42 research papers published in recent years. Different stages of our research process are given in Fig. 8.

VIII. Analysis Study

We have collected analytical findings from several research publications on UOWCs. Researchers have used different analytical approaches and designed communication systems, channel modeling, coding and modulation techniques. Researchers are working on innovative services, technical aspects, real world applications and emerging trend of UOWCs. The research challenges are found in proper exploitation of underwater environment before communication and clear understanding of propagation characteristics of channel. Possible solutions are found in simulations, laboratory artificial aquatic environment or test-beds. There is need of an effective approach for system design, testing and analysis before its final deployment in wide ocean environment. The analytical study must give confidence and significant results that designed system will meet the required performance and efficiency. Researchers should consider these analysis questions.

1) Designed system will meet real world application requirements?

2) Which modulation technique and signal processing tools will provide high performance?

3) What is the required communication range for data transmission between source and destination?

4) What is the best path for communication without delay in information transmission?

5) How to overcome temporary connectivity losses while communication?

6) How to control power utility in order to enhance system reliability?

7) How to cope with any possible threats and security attacks to achieve secure communication in network?

8) Which factors will mainly affect the UOWCs design, communication architecture and deployment?

9) Which factors will mainly affect the UOWCs design, communication architecture and deployment?

10) How to tackle transceiver position and orientation in LOS and NLOS conditions?

The researchers should consider these questions and find our factors to develop analysis techniques and solutions. Their solutions must validate the real systems. Research community should carefully address the reliability and feasibility of optical links in underwater scenario.

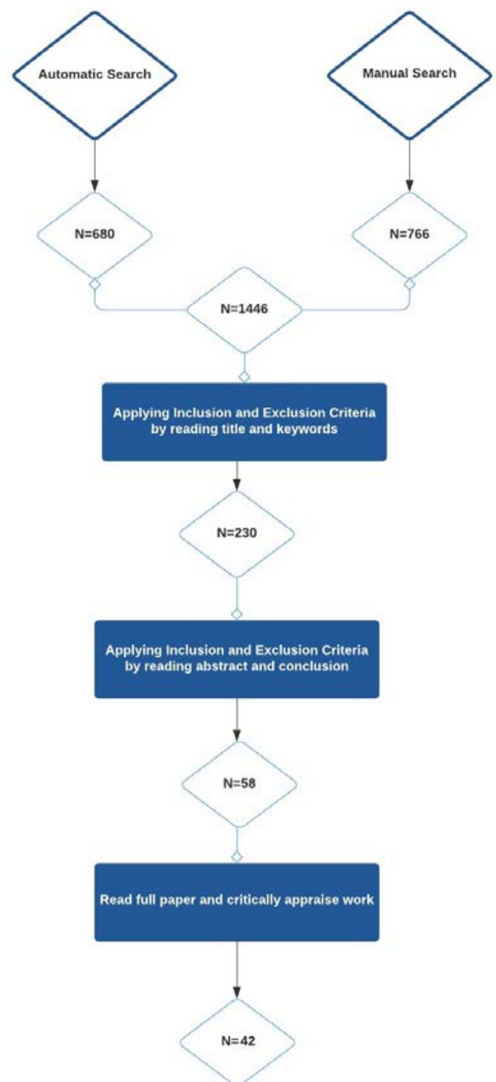

Fig. 8. Stages of Search Process.

IX. Research Validity and Limitations

We have found relevant research articles by using scientific keywords and references. We selected many papers from Google Scholar. In our exclusions, we selected relevant papers after reading title, abstract, conclusion and future aspects. A possibility of missing some recent papers or data still remains by using this keyword search, inclusion and exclusion methods. Here we have described the validity threats and limiting factors to this research study as follows:

1) Data sources: Our major sources for data collection were Google Scholar and ResearchGate. Though these sources are beneficial to search relevant data as they automatically fetch data from different databases, technical sources and academic publishers against single data query, but still we take it as a threat to validity as these sources suffer from certain limitations such as lack of search facility, partial control on content body and vulnerability to spam. To tackle this, we will include more sources, scientific search engines and publishers while extending our current work. Enabling this approach in extending our work, we are confident to get broader coverage of potential issues in UOWCs and will provide more statistical analysis.

2) Data collection process: While our data collection and analyzing process, we assigned a single researcher to read article and collect information from title, abstract and conclusion. It is a potential threat to validity of our findings and we tried to mitigate this concern through group discussion. We are aware that a single researcher can inject certain amount of inconsistencies in selected data. In future extended work, we will perform detailed statistical analysis through assigning this task to more than one researcher.

3) Selection of potential challenges: we tried to identify potential challenges of UOWCs. This investigation comes from preliminary analysis of different articles. Though we used an effective way to get appropriate analysis, still there can be more challenging factors. To alleviate this threat, one research member was assigned this task to keep a good record of possible challenges and issues discussed in each selected article. In the end, this approach provided confidence while validating our approach.

4) Time span: In inclusion criteria, we considered articles published after 2010 till now. Although it gives us right approach to find latest articles and key topics but it can affect the completeness of our search results as we did not include papers published before 2010. In future, we expect to involve more research recourses and considering articles published at a wide range of years.

X. Optical Wireless Revolution: 5G and 6G

Scientists have been focusing on 6G communication after the successful development of 5G networks. 6G is expected to be launched between 2027 and 2030. Although 5G communication has many advantages such as high-quality video streaming, internet TV and faster communication [40]; however, it does not support ground-breaking technologies as it mainly focuses on performance. While privacy, secrecy and security are main features of 6G communication [41]. In addition, research community should focus on security and privacy issues which exploit wireless communication such as channel fading and noise. In underwater environment, 6G network will assist to deploy UWSN nodes in the form of AUVs and sensors connected with underwater base stations. Recently, some countries have made strategic plan on revolutionary advances of 6G. German and U.K. governments have invested in quantum technology. China has also made official announcement that Chinese researchers are focusing on the development of 6G. Researchers from USA have started working on terahertz-based 6G mobile networks. Terahertz frequency communication offers 1000 times higher capacity than 5G networks. One goal of 6G is to achieve ubiquitous connectivity by integrating satellite communication networks and underwater communications to provide global coverage.

RF-based technologies are insufficient to meet the demand of 5G/6G and IoT networks. Therefore, OWC technologies are the best complementary solution of RF networks. A very large optical band is a good alternative as it offers prominent features of high security, low latency, high data rate, high QoE, massive connectivity, low cost and low energy consumption. The coexistence of RF and optical wireless systems can achieve the goals of such networks. OWC technologies, such as FSO, OCC, LiFi and VLC can be effective to deploy future 5G/6G and IoT networks. We have summarized data rates and latency in current backhaul technologies in Table XII. Optical fiber communication provides the highest throughput among all existing technologies. However, a similar throughput can be achieved in FSO as it has similar type of transceivers. In future, FSO network will emerge as promising solution to support higher data rates in 5G/6G networks.

TABLE XII. Data Rates and Latencies

Technology	**Latency**	**Throughput**
Optical fiber	<1 ms	100 Gbps
FSO	<1 ms	40 Gbps
mmWave	<1 ms	10 Gbps
Microwave	<1 ms	1 Gbps

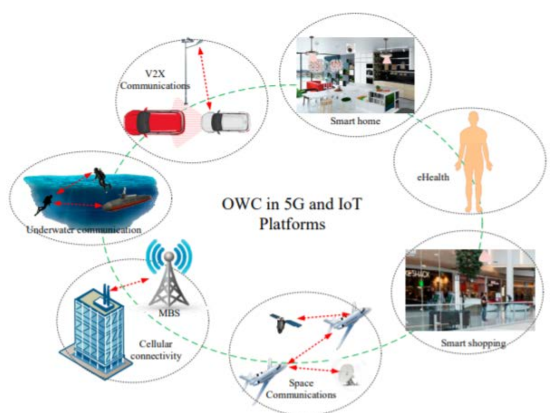

Fig. 9. OWC networks for the 5G/6G and IoT platforms [42].

OWC technologies can provide enormous number of connections through low-power LEDs to meet green aspects of 5G/6G and IoT networks. In addition, researchers should proficiently address some challenging issues such as atmospheric loss, flickering, inter-cell interference and frequent handover. A few important 5G/6G and IoT platforms using the OWC technologies are presented in Fig. 9.

XI. Conclusion

There is a growing need to dig into elementary acuity to make UOWC a reality in future. For this, a detailed analysis of theoretical models is required. Herein, we have highlighted some key research areas with profound knowledge in our systematic review. We have carefully addressed UOWC strategies which influentially affect remote communication. However, research fraternity needs to focus to enhance data rate for video transmission at larger distances. UOWCs will offer potential features in real life applications and will put more impact in future. Our main objective was to identify key challenges for future research. It is concluded from our study that researchers are putting relevant efforts to handle challenges in system design, deployments, link configuration and analysis of UOWCs. For a reliable and efficient optical link, we have discussed system architecture, channel modeling, modulation techniques and operating wavelengths in this research study. We also conclude that rapid ongoing research in UOWC will be more conducive in better performance with game-changing features in future.

XII. Future Work

We have highlighted a limitation of system with real time operating conditions and researchers must give specific concern as it will be beneficial to control remotely operated vehicles. As a precondition, research community should focus on developing intelligent modulation techniques to improve system performance. Future research should contemplate to involve Internet of Underwater Things (IoUT) to properly achieve real world applications. Researchers should pay attention to future 6G green communications. The coexistence of optical wireless and RF systems can meet the goals of such revolutions. Merging some latest underwater technologies with UOWC can bring promising results in future as shown in Fig. 10.

Besides all this, there is still room to develop cheap, adaptive, robust, highly stable, low powered and real time underwater optical sensors for an efficient UOWC system. In order to enhance overall robustness, adaptive techniques must be observed to save energy and optimize communication efficiency.

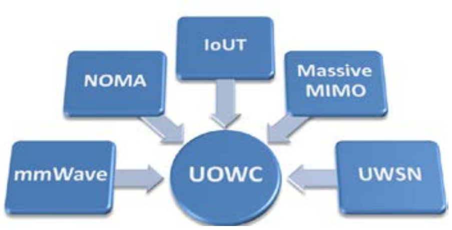

Fig. 10. Merging Underwater Technologies.

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Predicting Cervical Cancer using Machine Learning Methods

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***Abstract*—In almost all countries, precautionary measures are less expensive than medical treatment. The early detection of any disease gives a patient better chances of successful treatment than disease discovery at an advanced stage of its development. If we do not know how to treat patients, any treatment we can provide would be useful and would provide a more comfortable life. Cervical cancer is one such disease, considered to be fourth among the most common types of cancer in women around the world. There are many factors that increase the risk of cervical cancer, such as age and use of hormonal contraceptives. Early detection of cervical cancer helps to raise recovery rates and reduce death rates. This paper aims to use machine learning algorithms to find a model capable of diagnosing cervical cancer with high accuracy and sensitivity. The cervical cancer risk factor dataset from the University of California at Irvine (UCI) was used to construct the classification model through a voting method that combines three classifiers: Decision tree, logistic regression and random forest. The synthetic minority oversampling technique (SMOTE) was used to solve the problem of imbalance dataset and, together with the principal component analysis (PCA) technique, to reduce dimensions that do not affect model accuracy. Then, stratified 10-fold cross-validation technique was used to prevent the overfitting problem. This dataset contains four target variables–Hinselmann, Schiller, Cytology, and Biopsy–with 32 risk factors. We found that using the voting classifier, SMOTE and PCA techniques helped raise the accuracy, sensitivity, and area under the Receiver Operating Characteristic curve (ROC_AUC) of the predictive models created for each of the four target variables to higher rates. In the SMOTE-voting model, accuracy, sensitivity and PPA ratios improved by 0.93 % to 5.13 %, 39.26 % to 46.97 % and 2 % to 29 %, respectively for all target variables. Moreover, using PCA technology reduced computational processing time and increasing model efficiency. Finally, after comparing our results with several previous studies, it was found that our models were able to diagnose cervical cancer more efficiently according to certain evaluation measures.**

Keywords*—*Cervical cancer; machine learning; voting method; risk factors; SMOTE; PCA

I. Introduction

Cancer is a significant health problem, especially as it is one of the most common causes of death in many countries around the world. Breast, cervical and thyroid cancer are the most common types of cancer among women [1]. In the Kingdom of Saudi Arabia (KSA), cancer statistics are significantly increasing. The total number of cancer cases among women registered in the Saudi Cancer Registry (SCR) is 8,565 and cancer in females accounts for 52.8% of all cancer cases in the KSA. Cervical cancer was the fourth most common cancer among Saudi females in 2015, with 403 cases, representing 6.1 % of all cancer cases diagnosed among Saudi women [2]. In 2010, there were 220 cervical cancer cases among Saudi women, representing 4.1 % of all cancer cases, which indicates an annual increase of 9 % in the number of cervical cancer cases [3]. Since then, the number of cases increased even further, to 1073 by the end of 2018, according to a report by the World Health Organization [4].

Cervical cancer occurs and develops in a woman's cervix and is the leading cause of death from cancer among females. All women, at any age, are at risk of cervical cancer; however, it occurs most often in women who are 30 years of age and over. Human papillomavirus (HPV) is a virus that is transmitted from one human to another during sex and is the leading cause of cervical cancer. This virus infects at least half of the sexually active people at some point in their lives. Nevertheless, cervical cancer can be prevented by using a highly effective vaccine intended to prevent HPV infections [5] and the remaining number of cases can be reduced through early cancer detection using screening tests. If it is diagnosed early, cervical cancer is one of the most responsive to treatment forms of cancer and, thus, recovery can be very high [6]. The increasing of cervical cancer cases and deaths resulting from late diagnosis is the motivation behind this paper.

Cervical cancer is the second most prevalent type of cancer in the world. It arises in the mucous membrane ring that is called the cervical transformation zone, where cancer formed through four possible causes: persistent HPV infections in that zone, viral persistence, the persistence progression of a clones of infected cells that leads to cervical precancer and invasion. The risk of cervical cancer is mainly from infection with HPV and the lack of an effective examination [7].

The massive increase in data over the past years has led to the need to organize, analyze, and extract hidden knowledge from it. During this period, experiments demonstrated the effectiveness of machine learning in assisting experts to analyze data and predict results. Machine learning (ML) is a specific artificial intelligence (AI) branch that collects data from training data. ML technologies allow the computer to obtain knowledge from previous samples and use it to understand patterns from complex datasets. In the medical field, physicians have been able to improve the accuracy of detection, either of the presence or absence of diseases, to predict the disorders and to classify them. Therefore, researchers are seeking to build better ML models to analyzing medical data to obtain results that would assist the doctors in making correct decisions in diagnosing diseases [8].

This research provides an effective model for improving the performance of using machine learning methods and classification techniques for diagnosing cervical cancer to reduce mortality rates. It focuses also on the sensitivity and overall accuracy of the model to be certain whether patients really have cervical cancer disease or not. The results of this research can assist cancer researchers and physicians in diagnosing of cervical cancer. Then, they can begin treating the disease, thus increasing the patient's chances of recovery.

This paper is organized as follows. Section II discusses literature review and previous work. Section III describes research methodology including imbalance problem, feature selection and classification algorithms. Section IV describes Cervical cancer dataset, data pre-processing and missing data. Section V focuses on implementation and discussing the results. Section VI is the conclusion of the paper and finally Section VII discusses the future work.

II. Literature Review

A. *Cervical Cancer and Risk Factors*

The National Comprehensive Cancer Network (NCCN) has warned of the necessity of early detection of cervical cancer because the delay in its diagnosis is the main cause of an increase in the number of female deaths in the world [9]. Consequently, numerous medical and scientific research studies have been conducted that examine cervical cancer—its causes, symptoms and methods of detection and prevention. Scientists have also tried to identify the risk factors that cause the occurrence and development of this type of cancer.

Abdoh et al. [10] concluded in their research that the following factors pose the highest risk for the development of this disease: sexually transmitted disease (STDs), intra-uterine device (IUD), hormonal contraceptives and the age at which first sexual intercourse happens. Wu and Zhou [11] claimed that the number of sexual partners, the age when first sexual intercourse happens, the number of smoke packs smoked per year and the number of years that the patient uses hormonal contraceptives increase the possibility of developing cervical cancer. Nithya and Ilango [12] identified ten core features as being most important for predicting cancer.

Age plays a major role in increasing the risk of developing this disease. In Teame et al. [13], the researchers claimed that women 40–49 years of age are twice more likely to have persistent HPV infections than women under 40 and that women with a history of sexually transmitted diseases (STDs) are thrice more likely to have cervical cancer than others. Furthermore, the number of pregnancies, age, number of sexual partners, use of hormonal contraceptives and age at which first sexual intercourse occurred were the five risk factors identified by Deng et al. [14].

All the factors given above are used in this paper to perform analysis and generate results.

B. *Related Work*

ML algorithms are used in this research to efficiently detect cervical cancer by developing a model inspired by previous research models utilized in the same field.

Abdoh et al. [10] showed in their research that performance could be increased with traditional classification technique when using the synthetic minority oversampling technique (SMOTE) [10]. This study built a classification model using random forest (RF) that was based on cervical cancer risk factors. The results showed that the RF model, after applying SMOTE with all features of cervical cancer risk factors, outperforms the same model after applying two feature selection techniques in term of specificity and positive predictive accuracy (PPA). The two methods for selecting the features used in this study were recursive feature elimination (RFE) and principal component analysis (PCA). However, the researchers did not explain why the use of feature selection techniques was not effective in increasing the accuracy result. The dataset they used was gathered from the Universitario de Caracas Hospital in Caracas and is available at the repository of the University of California at Irvine (UCI) [10]. Wen Wu et al. [11] used the same dataset with three approaches to diagnosing cervical cancer: (1) support vector machine (SVM), (2) support vector machine principal component analysis (SVM-PCA) and (3) support vector machine recursive feature elimination (SVM-RFE). They concluded that SVM works well and gives results in specificity, positive predictive accuracy, and accuracy higher than the other two classifiers.

The voting and deep neural networks (DNN) classifiers were used with the same UCI dataset in [15] to build a model to predicting cervical growth. The voting classifier achieved the highest accuracy (97% to 99%) when compared to a DNN classifier. The author suggested using feature extracting in future works because it could help improve the predictor model.

A study by [14] used three types of ML algorithms to classify the UCI cervical cancer dataset after the Borderline-SMOTE application to handle dataset imbalance. After analyzing the results of the classifiers, XGBoost and random forest were found to better classify malignant and benign cancer than SVM. Because this dataset has a lot of missing values, F. Ashraf et al. [16] used four specific techniques to treat the null values. These techniques are the next observed carried backward (NOCB), last observed carried forward (LOCF), fill with median value and Fill with mode values. They used six ML algorithms: logistic regression (LR), random forest (RF), decision tree, naïve Bayes, neural network (NN) and SVM—to predict the Biopsy target variable. They concluded that the SVM and LR, when used with NOCB pre-processing, achieved the highest Precision, f1-score and accuracy. In another research study [17], Fernandes et al. presented a model that helped reduce learning dimensions and classified the UCI dataset using an artificial neural network (ANN). However, they did not fully explain how they dealt with the null values. In the end, they made a comparison between their model and the baseline model, which contained a deep-fed neural network and acquired a better accuracy than the baseline. This proposed model, through deep learning techniques accomplished accurate prediction results (the upper area under curve [AUC] = 0.6875).

On the other hand, A. Ghoneim et al. [18] proposed a new and effective model for predicting cervical cancer using the gene sequence module, but it will not be applied in our paper. The data they used consisted of private and public datasets. The private dataset was created from 472 questionnaires obtained from a Chinese hospital, where each patient who filled out her data in the survey had a corresponding gene sequence dataset. The public dataset was obtained from Universitario de Caracas Hospital in Venezuela and it includes 32 risk factors and 858 records. This study also addressed the challenges associated with previous studies on cervical cancer through adopting a voting strategy. This method helped predict disease because it is more practical and scalable effectively.

Unlike the dataset to be used in our paper, the Herlev database was used in the experiment by G. Muhammad et al. [19]. It contained 917 cells and 7 classes, with 3 classes representing normal cells and 4 classes representing abnormal ones. The study gave 242 normal and 675 non-normal images. A cervical cancer prediction and classification model that uses convolutional neural networks (CNNs) was proposed. The deep-learned features were extracted by feeding the cells images into the CNNs model. Subsequently, the extreme learning machine (ELM)-based, multi-layer perceptron (MLP) or autoencoder (AE)-based classifiers classified the input images. This proposed system with the ELM-based classifier accomplished a 99.7 % accuracy in the 2-class detection problem and a 91.2 % accuracy in the 7-class problem.

III. Research Methodology

Choosing appropriate methods and algorithms for a dataset is an essential step in building an efficient and accurate model. This section reviews possibilities for dealing with the imbalance problem in a dataset and appropriate ways of feature selection. Moreover, it discusses the classification methods and algorithms that were applied to the dataset:

A. Classification Algorithms

1) Logistic Regression: Logistic Regression (LR) is a statistical process, which has been increasingly used in medical research, especially in the past two decades. It is used to analyze a dataset when dependent variables are binary. LR as a predictive model helps obtain the relationship between one dependent binary variable and one or more independent variables. LR is distinguished by not assuming a linear relationship between the dependent and independent variables but by displaying a relationship between the output and predictive values [20].

The logistic curve that results from the logistic regression is between 0 and 1. This regression is similar to linear regression, but it uses the natural logarithm of the odds for the target variables in the curve creation process, instead of the probabilities. Furthermore, predictors are not required to have equal variance in each group or normal distribution.

2) Decision Tree: Decision Tree (DT) is one of the most frequently used machine learning algorithms. It is implemented to a dataset with the aim of classification or regression analysis. This algorithm divides the data into various subgroups based on a sequence of questions. The process begins with the primary node, which is called the root of the tree and containes all samples. Each node is split into secondary nodes in either a multi-split or binary form. For the construction of the tree, the "divide and conquer" approach is followed. This approach checks whether all the training samples have the same label or not. Subsequently, the training samples that have different labels are represented in a separate subtree [9], [18].

A DT has several advantages, including the ability to deal with many types of data, the processing of lost values, the ability to achieve good initial accuracy and the ease of implementation [16].

3) Random Forest: Random forest (RF) is one of ML algorithms. It is a supervised classification and ensemble technique that uses a set of decision trees to form a powerful learner. RF applies classification and regression tree (CART) technology to improve a not correlated combination or various decision trees based on bootstrap aggregation technologies. The aim is to find the correct classification and to know the relationship between the dependent variables (y) and independent variables (x) [10], [14].

Each tree is created randomly from a subset of the training set, using approaches like information gain or GINI index to create an independent decision tree (DT). The more trees, the more robust. Features classification and target variable are created independently from each DT, as if the tree votes for that class. Then, if there is a classification problem, the RF selects the classification that obtains the most votes; or, if there is a regression problem, it calculates the mean of all the trees [9], [21].

4) Ensemble Methods: Ensemble Learning (EL) as an effective technique has been adopted in recent years. It expands the traditional machine learning algorithm to combine multiple and stand-alone machine learning algorithms with improving overall classification accuracy. This technique has the advantage of mitigating the problem of having a small sample size by combining and averaging several classification models to decrease the possibility of overfitting the training data. In this manner, the efficiency of the training dataset can be increased, which is critical for various biological applications that have a small sample size. The purpose of using EL methods is to obtain a more accurate classification of training data and better generalization on unseen data [22], [23]. There are several methods of popular ensemble such as boosting, bagging, and voting.

- Bagging

In the bagging method, each classifier is trained on a group of samples and features to get a little varied classification hypothesis. Then, the classifiers are combined to form the ensemble. This method improves the generalization by decreasing variance [22].

- Boosting

In the boosting method, each classifier is trained and combined from the samples, but with several classification weights and different hypotheses. This method achieves the generalization by decreasing bias [22].

- Voting

The voting method is a good strategy to use if one classifier algorithm's defects can be an advantage for another classifier. The voting classifier incorporates the prediction outputs of the classifiers, selecting extremely predicted classes as class variables of test samples [24], as shown in Fig. 1.

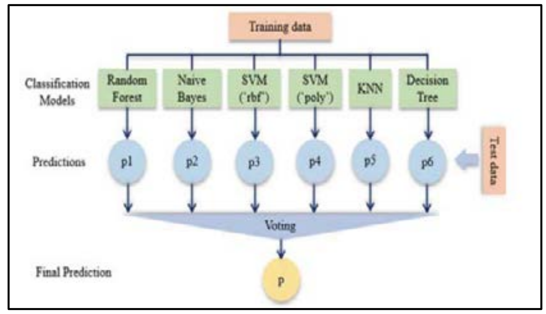

Fig. 1. Overall Structure of the Voting Method.

There are two voting method types: hard and soft voting. In hard voting, there is one vote for each stand-alone classifier. Then, the class label selected is the one which has a majority, that is more than half the votes. At the same time, the average class label probabilities are used as a voting score in soft voting. Then, the final class label should has the highest voting score or an average probability from each classifier [25].

B. Imbalanced Data

Any dataset can be considered as having an imbalance problem if the number of cases between the classes is not equal. In practice, when applying the classification algorithm to an unbalanced dataset, an exaggerated predictive accuracy is given because the predictive accuracy of the minority class does not exceed 10%. In comparison, the accuracy approaches for the majority class of 100% [20]. Sampling methods represent one of the best solutions for solving the data imbalance problem, which is based on the idea of modifying the distribution of the unbalanced dataset. Several studies have shown that classifiers have better performance with a balanced dataset when compared to an unbalanced dataset. Sampling methods consist of modifying the original dataset, either by increasing the minority class—which is called the oversampling technique—or by reducing the majority class—which is called the under-sampling technique—until the classes are represented approximately evenly [21].

- SMOTE: Synthetic Minority Over-sampling Technique

The simplest way to increase the size of the minority class is a random increase in sampling, but this method can cause overfitting. Hence, a new technique was proposed by Chawla et al. [20] —the synthetic minority oversampling technique (SMOTE)—for reducing the risk of overfitting that occurs when inserting duplicates of cases in the training set based on k-nearest neighbours [20]. SMOTE uses the following equation (1).

$$x_{syn} = x_i + (x_{knn} - x_i) \times t \tag{1}$$

Which x_i for feature vector, x_{knn} for the K-nearest neighbours and t for a random number between 0 and 1 [11].

C. Feature Selection

Feature selection algorithms help increase model performance. These algorithms have many benefits, such as reducing noise in the dataset, helping to increase understanding of the model's classification algorithms, and helping to simplify application, thus improving the model [22].

- PCA: Principal Component Analysis Feature Selection

PCA is a transformation process that can be used to decrease the number of features by extracting new, small, independent features without decreasing the model performance while maintaining the most critical required information contained in the original dataset. The correlated features can be combined as principal components in the statistical dimensionality reduction technique [22]. PCA is a mathematical process that defines the feature orientation based on the advantage of the eigenvector. Where the x-dimension feature space is converted into y-dimension, where y < x and the y-dimension feature space is known as a principal component. Then, the result of the covariance matrix is used to calculate eigenvectors and eigenvalues. the eigenvector with the highest eigenvalue is selected and this is the principal component of the cervical cancer dataset because it determines the important relationships between features the least important data is ignored. Finally, the data is shrunk from a high dimension to a lower one [11].

D. Validation (Cross Validation)

Cross validation (CV) technology refers to a resampling procedure for a limited data sample that can be used for validation and testing ML models. Cross-validation k-fold technology splits the dataset randomly into k (number of folds) identical parts. Then, one part is kept as validation data for model testing, while the residual k-1 parts are utilized as training data. The CV process is then repeated k times as various folds are used each time as the test set. The average of the k results from k-folds is then calculated to obtain a single result [26], [11].

Stratified K-Fold is different from k-fold, and it helps in dealing with an unbalanced set of data. First, stratified k-fold shuffles the data once before splitting and keeps each row with its label. Then, it splits data into k parts. The aim is to have the percentage of samples for each class to be similarly distributed across folds [17].

E. Evaluation Metrics

In biomedical data, the correct diagnosis of a cancer patient becomes important for ensuring a person's health, thus total accuracy is not used alone to evaluate the model. Consequently, several measurements, together with overall accuracy, are used to compare different models for the prediction of cervical cancer and to obtain explanations of diagnosed conditions. In this section, each of these measurements is reviewed.

1) Confusion matrix: The confusion matrix is a technique used for measuring performance in the form of a Table that contains information about both actual and predicted classes, as shown in Table I. If the proposed problem to be studied consists of an n row, this would result in the size of the confusion matrix being n*n, where the rows represent the actual row and the columns represent the expected row. The matrix describes actual and predicted values for two or more classes [27].

- True Positive (TP) indicates the number of correctly classified positive records.
- False Positive (FP) indicates the number of not correctly classified negative samples as positive records.
- True Negative (TN) indicates the number of correctly classified negative records.
- False Negative (FN) indicates the number of not correctly classified positive samples as negative records.

In the confusion matrix, a number of different metrics can be accessed that constitute the essential criteria for measuring model performance, including sensitivity (recall), specificity, f1-score, positive predictive accuracy (PPA) and negative predictive accuracy (NPA), together with overall accuracy.

Accuracy is a common metric, but it is inaccurate when used to measure the performance of an unbalanced dataset. It is the total number of correct predictions that have been achieved over the number of total predictions [24]. It is calculated by equation (2):

$$Total\ Accuracy = \frac{TP+TN}{TP+TN+FP+FN} \quad (2)$$

Sensitivity, also called the recall is the percentage of positives that are correctly identified from all the positives [8]. It is calculated by equation (3):

$$Sensitivity = \frac{TP}{TP+FN} \quad (3)$$

Specificity is the proportion of negatives that are correctly identified from all the negatives [8]. It is calculated by equation (4):

$$Specificity = \frac{TN}{TN+FP} \quad (4)$$

Precision, also known as Positive Predictive Accuracy (PPA), is the percentage of positive results that are true positive [11]. It is calculated by equation (5):

$$PPA = \frac{TP}{TP+FP} \quad (5)$$

Negative Predictive Accuracy (NPA) is the percentage of negative results that are true negative [11]. It is calculated by equation (6):

$$NPA = \frac{TN}{TN+FN} \quad (6)$$

F1-score is a harmony metric of Precision and Sensitivity on a single parameter and its range values are between 0 and 1, and it is better when it's closer to 1 [16]. It is calculated by equation (7):

$$F1 = 2 * \frac{\text{Precision}*\text{recall}}{(\text{Precisio}+\text{recall})} \quad (7)$$

2) Receiver operating characteristic (ROC) curve and area under curve (AUC): In clinical epidemiology, receiver operating characteristic (ROC) analysis is used to ascertain the accuracy of diagnostic medical tests that can distinguish between two cases of patients: the "diseased" and "non-diseased". It has received increasing attention in evaluating the performance of machine learning algorithms. The ROC curve depends on the idea of a separator scale, which results in outcomes for patients and non-patients.

The ROC curve is a graphical plot, where the Y-axis represents the (sensitivity) that given by equation (8), in contrast to the X-axis, where the (1-specificity) is given by equation (9). The closer the curve is to the upper and left borders of the ROC area, the more accurate the test [28], as shown in Fig. 2.

$$TPR = \frac{TP}{TP+FN} \quad (8)$$

$$FPR = \frac{FP}{TN+FP} \quad (9)$$

While the ROC curve is a perfect visual tool for recognizing a classifier's performance, sometimes a numerical value is needed for comparison purposes. The simplest way to calculate the value of the ROC is to measure the area under curve (AUC). The AUC is the percentage of a box's area under the ROC curve, where its values range from 0 to 1. The classifier's performance increases as the AUC value approaches 1 [24]. It is used to evaluate the performance of classifiers on data with an unbalanced distribution because it is unbiased against a minority class [29]. Also, the AUC of a classifier is equal to the chance that the classifier will rank a positive record as randomly chosen higher than a negative record [30].

TABLE I. THE CONFUSION MATRIX

		Predicted Values	
		Positive (1)	Negative (0)
Actual Values	Positive (1)	TP	FP
	Negative (0)	FN	TN

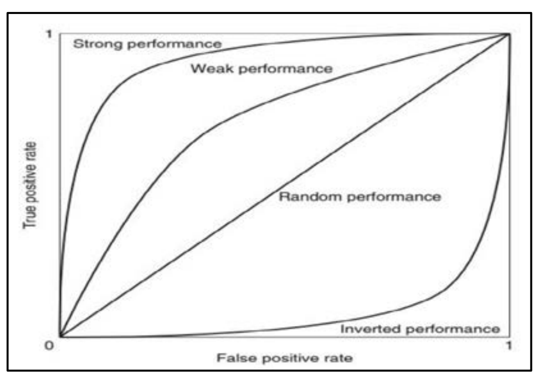

Fig. 2. The ROC Curve.

IV. Data and Analysis

A. Cervical Cancer (Risk Factors) Dataset

Cervical cancer dataset used in this paper was provided publicly by the University of California, Irvine (UCI) Machine Learning Repository, which is a collection of datasets and data generators that are employed by the ML community for the empirical analysis of ML algorithms [31]. David Aha created this archive and fellow graduate students at the university in 1987, as an FTP archive.

The dataset at the Hospital Universitario de Caracas in Caracas, Venezuela was collected in 2017. It focuses on predicting the diagnosis of cervical cancer for 858 cases, while it contains 32 features that display demographic information, habits and historical medical records for these patients as well as four target variables—Hinselmann, Schiller, Cytology and Biopsy—which constitute the main diagnostic methods for cervical cancer [32].

These four target variables were used as classification labels to classify the dataset by machine algorithms [33]. The descriptions and types of the 32 features are shown in Table II.

TABLE II. DESCRIPTIONOF DATA ATTRIBUTES

No.	Attribute	Type
1	Age	Int
2	Number of sexual partners	Int
3	First sexual intercourse (age)	Int
4	Number of pregnancies	Int
5	Smokes	Bool
6	Smokes (Years)	Bool
7	Smokes (pack/Years)	Bool
8	Hormonal Contraceptives	Bool
9	Hormonal Contraceptives (Years)	Int
10	IUD	Bool
11	IUD (Years)	Int
12	STDs	Bool
13	STDs (number)	Int
14	STDs: condylomatosis	Bool
15	STDs: cervical condylomatosis	Bool
16	STDs: vaginal condylomatosis	Bool
17	STDs: vulvo-perineal condylomatosis	Bool
18	STDs: syphilis	Bool
19	STDs: pelvic inflammatory	Bool
20	STDs: genital herpes	Bool
21	STDs: molluscum contagiosum	Bool
22	STDs: AIDS	Bool
23	STDs: HIV	Bool
24	STDs: Hepatitis B	Bool
25	STDs: HPV	Bool
26	STDs: Number of diagnosis	Int
27	STDs: Time since first diagnosis	Int
28	STDs: Time since last diagnosis	Int
29	Dx: Cancer	Bool
30	Dx:CIN	Bool
31	Dx:HPV	Bool
32	Dx	Bool

B. Cervical Cancer and Risk Factors Dataset Concerns

In this paper, a small cervical cancer and risk factors dataset has been used with a heavy class imbalance. Fig. 3 shows the ratio of positive and negative results for cervical cancer obtained through the main diagnostic methods that represent the four target variables. The synthetic minority oversampling (SMOTE) technique was used to solve the imbalance problem. It is a statistical method that aims to increase the number of records in a balanced way. This method generates new cases in the dataset based on existing minority cases provided as inputs. With SMOTE, majority instances remain unchanged [34]. The use of repeated K-fold cross-validation also plays an active role in the dataset with limited observations [35]. Mitigating the problem of a small dataset is one of the advantages of ensemble technologies. Ensemble learning is an effective method that combines multiple learning algorithms and classification models, which helps improve overall prediction accuracy and reduces the possibility of overfitting the training data [22].

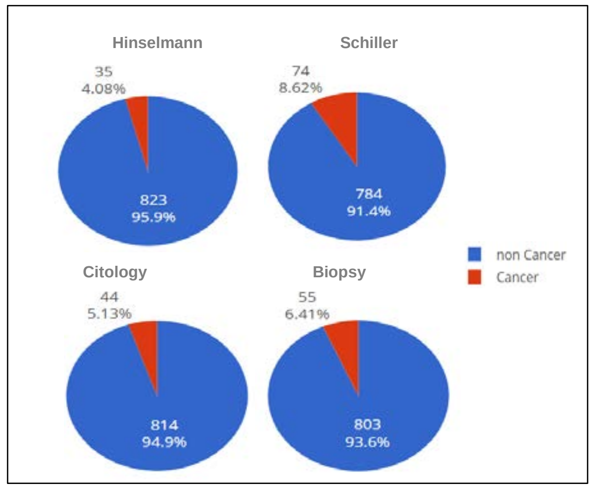

Fig. 3. Summary of the Percentage of the Four Target Variables in the Cervical Cancer Dataset.

C. Data Pre-Processing

The extraction of valuable information and results depends mainly on the quality of the data, while the medical data is affected by some factors that affect its quality, such as missing values, noisy data, inconsistencies, and outliers. Therefore, it is necessary to process the data before starting the machine learning process, where the data pre-processing is an essential step for raising data efficiency. Data pre-processing includes data preparation and dataset transformation that makes knowledge discovery more effective [34]. In this paper, the following steps were used to pre-process data:

1) Missing data: Missing data refer to the data values, which are not stored for a variable or attribute in the dataset [36]. Missing data pose a significant problem in the data analysis process because it is very common for data to be lost, especially in medical data [37]. Missing data is very critical because most analytical methods cannot be applied to an incomplete dataset as this greatly affects the quality of the machine learning model. Therefore, missing values must be dealt with in calculating missing values with reasonable values [38]. Some algorithms, such as scikit-learn methods assume that all values are not missing and have a meaningful value [39].

The cervical cancer dataset contains many blank values, and this is due to some patients who did not answer some questions because of their individual privacy [31]. There are two approaches to handling missing data in the cervical cancer dataset: ignore (remove) missing values or impute (fill) missing values.

2) Ignore missing values: Ignoring some features contributes to making data consistent due to the high percentage of missing values in them. This approach is useful because some features have missing values in the dataset, such as the "Time since first diagnosis" and "Time since last diagnosis", where their missing values were greater than 80 % of all data in these two attributes. Due to the difficulty in filling in such a large proportion of missing values with meaningful values and not finding any attribute dependencies that can be used to derive values for the missing data, these two attributes were excluded [11], [12], [16].

3) Impute missing values: Imputation methods is one of the common methods in the field of missing data that fill missing values with appropriate values [40]. There are many features in cervical cancer dataset with the missing values less than 20%. These missing values were recorded as "?" in the dataset and imputed in one of the following two ways:

- Imputation using the mean values: This is the most common of imputation techniques [41]. This method is conducted by calculating the mean value of non-missing data in a specific column and then the missing values are replaced with this value in that column.
- Imputation using decision tree: In 1982, Kalton and Kasprzyk were the first proposing the use of a decision tree to handle lost data [42]. In this method, the sklearn Iterative Imputer class was used with a decision tree regressor for numerical data and a decision tree classifier for categorical data. Instead of ignoring a feature that has missing values, the decision tree imputation was used to convert the lost value of that feature to some calculated value. Thus, the decision tree imputation predicts the imputation value based on other values in the dataset. Where the feature that contains missing values is used as a target, the remaining attributes are used as training data. After fitting the model, the missing values are identified as if they were class labels [43], [44]. The advantages of this method are it produces more accurate values and is available for both categorical and numeric variables; however, it is also more time-consuming [45].

4) Data transformation: In data transformation step, the data is converted or consolidated so that the processing results are more efficient, and it is easy to understand the existing patterns. Then, the data becomes suitable for processing and applying machine learning algorithms [23].

Normalization is one of the data transformation strategies, which refers to the process of scaling the values of features to be within a small specified range or common range, such as [0,1] or [-1,1]. There are many normalization methods, such as Min-Max, decimal and Z-score normalization. Min-max normalization was applied to this dataset.

5) Outliers: In a dataset, finding outliers is a challenging and complicated process, especially for high-dimensional datasets. The outlier refers to an observation or a subset of observations that appear to be inconsistent with the rest of the dataset, while the outlier detection refers to searching for objects in the dataset that are not subject to the laws that are valid for the main part of the remaining data [46].

In medical data, the leading causes of outliers are malfunctions of medical devices, human errors, patient-specific behaviors, natural change in the patient, medication intake, food or alcohol, stress, and others [46]. In some cases, the outlier value provides useful information because it may indicate a rare disease and, therefore, outlier values are usually treated by keeping, removing, or modifying them. In this paper, outlier values were preserved because these values explain the situation of people in society and their differences [47].

V. Implementation and Results

A. Implementation

As we mentioned previously in the research methodology section, three main steps were used. The first step was choosing and understanding the dataset. The second step was pre-processing the original data for classification and handling data imbalance. The last step involved feature selection and building a model based on useful prediction classification (see Fig. 4).

In the modelling stage, four predictive models were implemented for each target variable to compare their results and then to determine the best model based on its ability to detect cervical cancer. These predictive models were conducted using the Jupyter Notebook, which is an open-source environment that allows editing and running of Python 3.3 programming language. There are several Python libraries that have been used to build these models, such as Scikit-learn, matplotlib, NumPy and pandas.

After data pre-processing, the feature reduction technique, PCA with 11 principle components, was used to decrease the number of features and processing time. Then, the dataset was split into training and testing sets. Due to the unbalanced dataset, SMOTE technology was applied to the training set to achieve balance to the minority class highest accuracy and avoid classification mislead.

The voting classifier was applied, which is one popular ensemble method. The voting classifier combined the prediction outputs of three classifiers: logistic regression, random forest, and decision tree, as shown in Fig. 5, and extremely predicted classes were selected as class variables of test samples. Then, the stratified 10-fold cross-validation (CV) method was used to prevent the overfitting problem and for the validation and testing of data. Subsequently, the result of the model was assessed using different evaluation metrics, such as accuracy, sensitivity, specificity, precision (PPA), NPA, f1-score and ROC_AUC.

For the four predictive models, the voting classifier was applied to them all to focus on the impact of SMOTE and PCA technologies on model performance and to compare them. The first model was built without applying any of these two technologies, the second model contained PCA only, the third one contained SMOTE only and both techniques were applied to the fourth model.

B. Evaluation and Results

The results of the four predictive models for each target variable are discussed in the following sections.

1) Target variable: Hinselmann: With the Hinselmann test, there were 823 benign and 35 malignant samples. The voting model before SMOTE achieved a total accuracy of 95.69 %, while after using SMOTE it achieved an accuracy of 96.62 %. The accuracy increased after using SMOTE by 0.93 %, the sensitivity ratio increased from 50 % to 96.97 % and the ROC_AUC metric rate increased from 64.17 % to 97.75 %, as shown in Table III.

SMOTE-voting-PCA works well with 11 principal components. In this case, the negative predictive accuracy, and the ROC_AUC scale already reached 99%. In comparison with the voting before SMOTE, SMOTE-voting-PCA increased the sensitivity and precision rates by 46.50 % and 30.99 % respectively. Also, the overall accuracy of SMOTE-voting-PCA was nearly 97%. Accordingly, SMOTE and PCA methods can basically actualize the action of the voting classifier.

Fig. 6 shows the superiority of the voting classifier performance compared to the three classifiers—logistic regression, random forest, and decision tree—in the SMOTE-Voting -PCA model of the Hinselmann target variable.

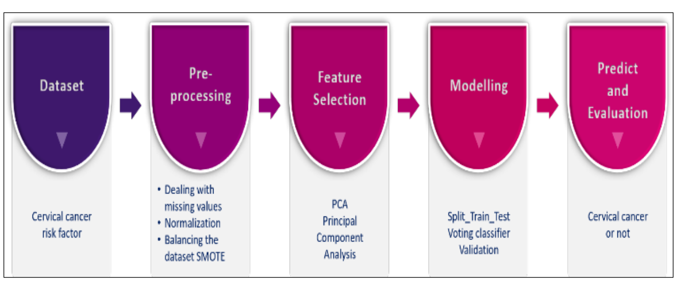

Fig. 4. Methodology Process.

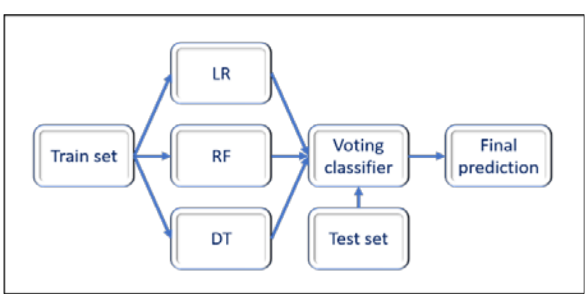

Fig. 5. Voting Classifier Workflow.

TABLE III. EVALUATION OF PREDICTIVE MODELS OF THE HINSELMANN TARGET VARIABLE

Evaluation Metrics %	Before SMOTE		After SMOTE	
	Voting	Voting-PCA	SMOTE-Voting	SMOTE-Voting -PCA
Accuracy	95.69	95.93	96.62	96.73
Sensitivity	50.00	50.00	96.97	96.50
Specificity	100	100	97.69	97.69
PPA	48.00	48.00	77.00	78.99
NPA	95.92	95.92	98.53	98.77
F1-score	49.00	49.00	96.39	96.85
ROC_AUC	64.17	57.04	97.75	98.56

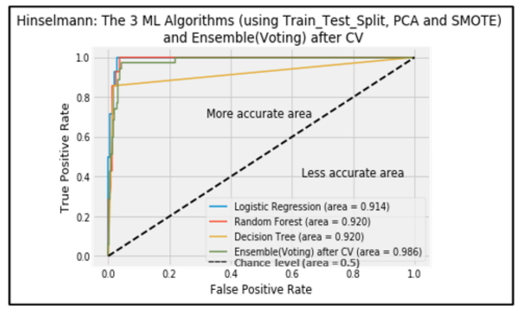

Fig. 6. The ROC Curve for the SMOTE-Voting-PCA Model of the Hinselmann Target Variable.

2) Target variable: Schiller: Concerning Schiller's test, the voting classifier before SMOTE achieved an overall accuracy of 90.09% with 74 patients and 784 non-patient samples. After SMOTE, SMOTE-Voting achieved an accuracy of 95.22 %, while the sensitivity increased by 39.87 %, PPA by 23.47 %, NPA by 5.46 % and ROC_AUC by 23.39 % in comparison to the voting model.

In voting-PCA with 11 principal components, the sensitivity, NPA and f1-score decreased by 2.00%, 0.42% and 4.00%, respectively, in comparison with the voting model. In contrast, the SMOTE-voting-PCA model for Schiller test with 11 components obtained the highest ratios in accuracy, sensitivity, PPA, NPA and f1-score, as shown in Table IV. Likewise, the ROC curve of SMOTE-voting-PCA in Fig. 7 shows that the model has the highest ROC_AUC in comparison to other models.

TABLE IV. EVALUATION OF PREDICTIVE MODELS OF THE SCHILLER TARGET VARIABLE

Evaluation Metrics %	Before SMOTE		After SMOTE	
	Voting	Voting-PCA	SMOTE-Voting	SMOTE-Voting-PCA
Accuracy	90.09	90.33	95.22	98.49
Sensitivity	55.00	53.00	94.87	98.60
Specificity	96.94	98.60	97.19	98.98
PPA	61.00	62.00	84.47	95.16
NPA	92.23	91.81	97.69	99.49
F1-score	57.00	53.00	95.11	98.37
ROC_AUC	68.17	61.78	91.56	99.80

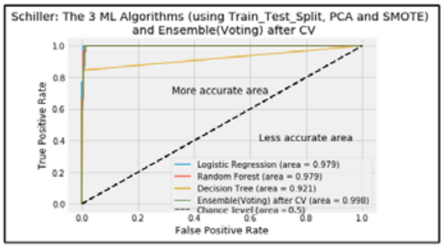

Fig. 7. The ROC Curve for the SMOTE-Voting-PCA Model of the Schiller Target Variable.

3) Target variable: Cytology: In the Cytology screening test, the voting model before SMOTE achieved a total accuracy of 94.29% with 44 malignant and 814 benign samples. This is considered to be a better result than the voting model after SMOTE, as the accuracy after SMOTE decreased to 91.72%, but the sensitivity and ROC_AUC rate increased to 91.26% and 72.30%, respectively, in the SMOTE-voting experiment.

In the SMOTE-voting-PCA model with 11 principal components, the ratio of four measures increased—NPA, f1-score, ROC_AUC and sensitivity—in comparison to the other models, reaching 97.84 %, 93.35 %, 93.90 % and 93.12 %, respectively, as shown in Table V. The remaining measures—accuracy, specificity, and PPA—decreased by 1.98 %, 5.16 % and 3.21%, respectively in comparison to the voting-PCA model.

It can be concluded that, for the Cytology test, the SMOTE-voting-PCA model obtained the highest ROC_AUC, sensitivity, PPA and NPA ratios in comparison to the rest of the models, as shown in Fig. 8.

4) Target variable: Biopsy: In a biopsy test, the accuracy of the voting model without SMOTE reached 93.24 % with 55 malignant and 803 benign samples. Table V shows that the performances of the voting and voting-PCA before SMOTE models were somewhat similar in most evaluation metrics.

After SMOTE, when comparing the models SMOTE-voting and SMOTE-voting-PCA, the accuracy, sensitivity, PPA, NPA, and ROC_AUC increased in the SMOTE-voting-PCA model by 2.22%, 1.99%, 6.6%, 0.89% and 4.64%, respectively. Thus, according to the evaluation results in Table VI and the ROC curves shown in Fig. 9, the SMOTE-voting-PCA model with 11 principal components was able to predict cervical cancer via a Biopsy test better than other models. This clarifies the role of the two technologies in raising the performance of the model, whether with a biopsy test or with the previous three tests—Hinselmann, Schiller and Cytology.

C. Discussion and Comparison

From the previous results, the voting method helped increase the performance of the models in comparison to other classifiers and to obtain a good accuracy in the classification of cervical cancer data. However, the somewhat high accuracy rate during the classification was offset by a low sensitivity rate, ranging between 50% and 53%, in all previous experiments of the four target tests. Where many patients were classified as non-patients that is incorrect and medically unacceptable classification. This defect is due to the limited and unbalanced dataset. Hence, the SMOTE algorithm was used to solve this problem and create new samples synthetically, thus increasing the data of cervical cancer patients. After using SMOTE technology in the SMOTE-voting model, accuracy, sensitivity and PPA ratios improved by 0.93% to 5.13%, 39.26% to 46.97% and 2% to 29%, respectively, for all target variables. PCA technology was also used to reduce the features to 11 principal components, thereby reducing computational processing time and increasing model efficiency. Experiments showed that SMOTE and PCA technologies have greatly helped classify cervical cancer data correctly for all target variables.

The top 10 relevant risk factors of cervical cancer of these target tests are the features 0 and 2 that indicate age and first sexual intercourse according to Table II, and these features appear in the first three ranks for all target tests, while feature 8, which indicates hormonal contraceptives, appears in three of the four tests. Fig. 10 shows the top 10 relevant risk factors for the Biopsy target variable.

When comparing our results to the results of Wu and Zhou [11] shown in Fig. 11, we found that the SMOTE-Voting-PCA model outperforms the accuracy and specificity of the SVM-PCA model in the Hinselmann and Cytology tests. In contrast, our models of the Schiller target variable obtained better results in four measures: accuracy, specificity, PPA and NPA. With the Biopsy test, the accuracy, specificity, and PPA of our model increased after SMOTE in comparison to the non-SMOTE models proposed by Wu and Zhou [11].

TABLE V. EVALUATION OF PREDICTIVE MODELS OF THE CYTOLOGY TARGET VARIABLE

Evaluation Metrics %	**Before SMOTE**		**After SMOTE**	
	Voting	**Voting-PCA**	**SMOTE-Voting**	**SMOTE-Voting-PCA**
Accuracy	94.29	94.87	91.72	92.89
Sensitivity	52.00	52.00	91.26	93.12
Specificity	99.14	99.75	95.21	94.59
PPA	59.00	73.00	61.00	69.79
NPA	95.05	95.08	96.27	97.84
F1-score	52.00	53.00	91.14	93.35
ROC_AUC	60.48	48.02	72.30	93.90

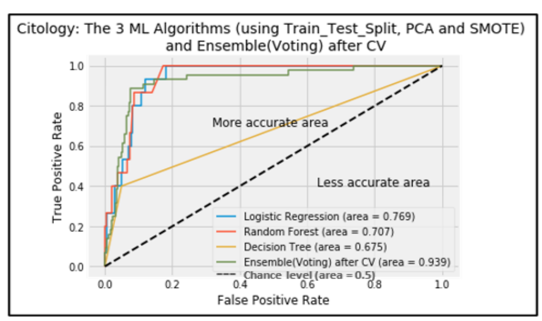

Fig. 8. The ROC Curve for the SMOTE-Voting-PCA Model of the Cytology Target Variable.

TABLE VI. EVALUATION OF PREDICTIVE MODELS OF THE BIOPSY TARGET VARIABLE

Evaluation Metrics %	Before SMOTE		After SMOTE	
	Voting	Voting-PCA	SMOTE-Voting	SMOTE-Voting-PCA
Accuracy	93.24	93.36	95.22	97.44
Sensitivity	51.00	52.00	95.80	97.79
Specificity	99.25	99.50	96.64	98.01
PPA	59.00	64.00	83.01	89.61
NPA	93.76	93.78	98.10	98.99
F1-score	51.00	52.00	95.22	97.44
ROC_AUC	65.55	52.47	94.86	99.50

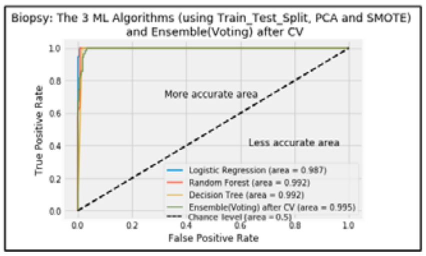

Fig. 9. The ROC Curve for the SMOTE-Voting-PCA Model of the Biopsy Target Variable.

Fig. 10. The Importance of Features for the Biopsy Target Variable.

Fig. 11. The Comparison of the Results of SMOTE And non-SMOTE Models for the Four Target Variables.

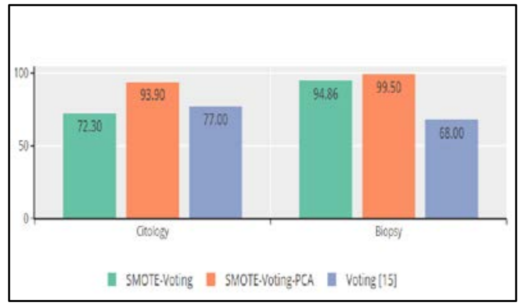

Fig. 12. Comparison of the ROC_AUC Measure for the Cytology and Biopsy Target Variables.

In Fig. 12, ROC_AUC was compared between the models we propose (SMOTE-Voting and SMOTE-Voting-PCA) and the voting model proposed by Rayavarapu et al. [15]. This comparison confirms the roles of SMOTE and PCA techniques in raising model performance.

VI. CONCLUSIONS

An early detection procedure provides the best opportunity for diagnosing cervical cancer at an early stage of the disease when the treatment is more beneficial. Cervical cancer, if detected early, is one of the most successfully treatable types of cancer. The paper is focused on finding a model capable of diagnosing cervical cancer with high accuracy and sensitivity using machine learning algorithms, as well as on trying to find a method for dealing with an unbalanced dataset, where the imbalance problem reduces predictive efficiency and increases misleading classification. In this paper, we combined the best three classifications of machine learning algorithms to predict cervical cancer and obtain the highest results using one of the ensemble approaches, which is the voting method. Four predictive models were created using the UCI cervical cancer risk factors dataset for each of the targeted variables: Hinselmann, Schiller, Cytology and Biopsy. The proposed models introduce new built-in classifications, which collect certain techniques, such as the SMOTE to increase the number of minority cases to rebalance the dataset and the PCA technique to reduce the dimensions that do not affect the accuracy of the model. From the results obtained, the voting method with SMOTE and PCA technologies helped classify cervical cancer data correctly for all target variables and raise the accuracy, sensitivity, and ROC_AUC of predictive models to high rates as in the Schiller target variable, they reached to 98.49%, 98.60%, and 99.80%, respectively.

VII. FUTURE WORK

In our future work, the dataset used to detect cervical cancer can be improved and the efficiency of future prediction models can be increased by adding several essential attributes that assist early detection of cervical cancer. Some information could be collected and added to the dataset. For example, whether the Pap smear was performed recently and whether an HPV vaccination was given. This additional information can be collected from patients and clinics so that the extensive dataset will assist in building a better predictive model. Moreover, adding several essential attributes will also improve the prediction model for early detection of cervical cancer.

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Students' Perception of the Effect of Cognitive Factors in Determining Success in Computer Programming: A Case Study

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***Abstract*—The reliance on science and technology by both countries and corporate entities is increasingly evident as the evolving trend of digitization not only pervades every facet of life but also assumes a dominant role. Correspondingly, the significance of producing competent computer science and information technology (IT) graduates becomes highly imperative. Already, in most developed and developing countries, there has been an increasing demand for these competencies such as network engineers, programmers, and other IT-related specialists. Although these competencies are equally valuable, programming skills constitute the core of the strength of every other IT-related competence. Nevertheless, programming is reported in the literature to be one of the most difficult courses to students. Moreover, the level of performance in programming is said to be significantly low with an attendant high rate of students' dropout. There is a concerted research effort toward addressing the challenge of poor academic performance by attempting to answer the question of what factors affect academic performance in general. However, there is scanty literature on the factors that affect the ability to understand the concept of programming in specific. This paper, therefore, reports a case study investigation of students' perception of the effect of cognitive factors as the determinant of success in computer programming. The findings showed that performance in introductory programming is impacted by a range of interrelated cognitive factors including self-efficacy and the love for technology.**

Keywords—Cognitive factors; performance; programming; self-efficacy

I. Introduction

Under-performance and a high dropout rate of undergraduate students remains a major problem that characterized higher education in South Africa [1], [2]. This predicament has tremendous adverse implications on both the private and public sectors of the economy because students are the potential assets of the country's economy as they transfer skills from the Universities to the industry. The government commits huge budgetary allocations annually through the Department of Higher Education and Training as part of a broad national strategy to improve the quality of life of South Africans by supporting the post-school education and training system.

Among others, science and technology disciplines record the lowest performance and highest dropout rates. Within South African Universities of Technologies as well as other countries, this ugly trend of poor performance is very pronounced among first-year students, especially in introductory programming courses [3]. Moreover, under-performance in programming has far-reaching implications. For instance, it can undermine the capacity to meet the global trend of a shift in skill demand in response to the advent of the Fourth Industrial Revolution (4IR) [4], [5]. This revolution hinges on digital technology as the pivot and driver of global innovation because it ushers in a paradigm shift from the hardware-centered to software-centered technology [5].

Whether for the student, researcher, or industrialist, the transition to 4IR, promises unlimited prospects in the emergent fields of Internet of Things, cloud computing, artificial intelligence, machine learning, and big data analytics. From a labour market perspective, these prospects present an ever-growing global demand for the IT skills necessary to steer the resultant digital economic, social, and other innovative systems in both developed and developing countries [6], [7]. This realization essentially emphasizes the indispensability of computer programming skills in an increasingly IT-dominated world. Therefore, it becomes highly imperative for universities that offer IT courses to strengthen their capability to produce graduates with sound programming skills.

Consequently, the need to address underperformance in programming has gained wide research attention with much emphasis on identifying the predictor factors [8], [9], [10].

However, with the global average success rates in introductory programming courses estimated to be 67 percent in [11], the need to investigate why several students find introductory programming difficult [3] to understand remains highly imperative.

In this study, therefore, the perception of students on the effect of cognitive factors as a predictor of academic performance in computer programming was investigated. The study contributes toward enhancing curriculum development for South African Universities of Technologies and providing useful insights for crafting intervention programs to assist at-risk students. The study used a case study of second-year Information Technology students at a South African University of Technology.

The rest of the paper is structured as follows: the review of relevant works in presented in Section II and the cognitive learning theory briefly explored briefly explored Section III. The study's methodology and case study description are offered Sections IV while the findings are reported in Section V. The paper in concluded in Section VI.

II. Literature Review

With the emergence of Big data analytics and machine learning tools, several models are being designed to predict academic performance in diverse fields as reported in [12]–[14]. Such models are grounded on the rationale that academic performance is the resultant effect of certain determinable variables or factors. As researchers seek to understand the phenomenon of academic performance, these factors have been the key focus of various investigations. Therefore, this review is strucrured based on the categories of factors as reported in the literature, namely, academic factors, cognitive factors, and psychosocial factors.

A. Academic Factors

Factors such as previous academic achievement, mathematical abilities, prior experience, and study skills have widely alluded by many studies to have a strong correlation with academic performance. In their work to rate predictor factors, authors in [15] maintained that previous academic achievement is a single best predictor of student success at the university level. According to the authors, a student who obtained good results in high school is likely to perform better in the university. This finding is also supported in [16]. In a similar effort reported in [17], students' previous achievement was found to best predict their academic performance when combined with self-efficacy.

Another work in [18] narrowed the focus to investigate the joint effect of prior programming background and self-efficacy on undergraduate students' success in programming. Based on their findings, they concluded that prior programming does not affect performance directly, but it increases one's self-efficacy for programming hence increase performance. In the same vein, the relationship between mathematics and programming was investigated in [19]. The study confirmed that students' mathematics ability was strongly related to their programming performance. Similarly, other studies such as using a mixed-method approach, the work in [20], [21] all corroborate the strong correlation between mathematics abilities and performance in programming. Authors in [21] specifically stated, "The data shows that if the mathematics subject result is good, then the programming result is also good".

B. Psychosocial Factors

There have been consistent reports in the literature that psychosocial factors impact academic success. Psychosocial factors such as students' social integration, career orientation, commitment to the study, social support, psychological health, amongst others have been investigated. According to [22] Tinto's theory indicate that a student tends to persist and perform better if integrated well to the university. This claim is also strongly supported by the findings reported in [23]. But contrary to Tinto's model, the work in [24] revealed that the commitment of students to the university's social activities results in poor performance. This may be true for courses like programming which require a lot of time. Too much involvement of students in the university social groups may occupy the very time required for practice since computer programming requires practice in and out of the classroom. However, the authors further concluded that students who like the course they study are often associated with clear objectives and are likely to obtain good results.

C. Cognitive Factors

There is extensive research on potential effect cognitive factors on academic success. The majority of these studies focus more on first-year students. The reason for this is because according to [25], the students tend to drop out of the university during the first academic year or before the second year of study as a result of poor academic achievement. Poor performance or dropouts of students is a concern to the academic institutions. Numerous studies have identified several cognitive factors to influence academic achievement. These factors include but not limited to mental models, self-efficacy beliefs, motivation, and personality traits. However, self-efficacy and motivation have been for a long time, indicated as having a strong impact on the academic success of students.

Studies on self-efficacy have constantly asserted that students with high self-efficacy are likely to achieve good results at university than those with low self-efficacy. The work in [26] noted that self- efficacy has been proven across the literature as the strongest predictor of academic performance. The author of the work in [27] is also convinced that self- efficacy is a powerful predictor of academic performance. According to the author, every action one could take starts in the mind. Thus, "people's beliefs in their efficacy influence the type of anticipatory scenarios they construct and rehearse".

The work in [28] studied the effect of self-efficacy, mathematics, self-concepts, perceived usefulness of mathematics, and prior experience with mathematics on the prediction of problem-solving. Their study revealed that mathematics self-efficacy was the best predictor of problem-solving. The work did not examine the joint effect of these factors because the findings in [29] support the fact that self-efficacy tends to increase for one with prior experience. A study conducted in [30] examined the influence of combining self-efficacy, mental model, and prior introductory programming experience and it was discovered that self-efficacy of a student with previous programming experience tends to increase significantly throughout the programming course in the first-year level.

III. Cognitivism and Cognitive Factors

Cognitivism as a learning theory explains how mental processes are influenced by both external and internal factors to produce learning in an individual. The theory is centred on the idea that learning occurs when individuals process information they receive, rather than merely responding to stimuli as illustrated in Fig. 1. That is, the individual takes in the stimulus, processes it in their mind, and then acts upon the stimulus, which alludes to the fact that in the cognitive learning process, new knowledge is built upon prior knowledge.

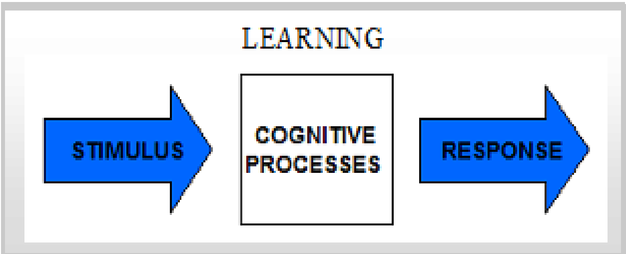

Fig. 1. The Cognitive Learning Process.

The mental processes that leads to learning consist of several elements of the individual which include attention, observation, perception, reasoning, organizing, memory, and forming generalizations. These elements or factors represent those characteristics of a person that affect the way they learn and perform [31].

Essentially, cognitive factors are intrinsic characteristics, therefore, they cannot be measured qualitatively. However, as learned in the literature, cognitive ability is associated with some perceived behavioral attitudes also referred to as cognitive predictors. Based on this understanding, the data for this study was obtained by measuring students' perceptions of the cognitive predictors that influence performance in introductory programming.

IV. Case Study Description and Methodology

This case study was structured in a manner that allows the researches to explore the effect of cognitive factors on a total of 20 selected second-year students. The study population was then categorized into two subgroups based on the students' first and second semesters average performances in their first year. Each subgroup was further partitioned into two equal focus groups. To ensure confidentiality and avoid stigmatization, the basis of the categorization was not disclosed and neither of the two groups knew about the existence of the other. More importantly, it was presumed that participants may not be willing to give out honest information should they know that the investigation equally involves some other students who might know them.

The first subgroup consists of ten students who had an average score of less than 50% in their first and second semester year one introductory programming. The data was officially obtained from the department of information and communication technology by one of the researchers who facilitates the course. Scores within that range depict a poor to fair performance. This categorization condition was intended to enable the us to evaluate the students' perception on how cognitive factors may relate to their performance. On the other hand, the second subcase comprised of another ten students whose average score is 50% or higher. Similarly, this score range of identified students of good to excellent performance.

Because this study investigates a real-world problem, the methodology is designed to ensure flexibility in the process of gaining concrete and in-depth contextual knowledge through two data collection tools – unstructured questionnaires and focus group interviews. Qualitative data may be broader and richer [32], but it may also suffer the deficit of being less precise. Consequently, the strategies of data triangulation and prolonged involvement strategies to enhance precision and strengthen the validity of the study as outlined by Robson and other authors [33] were utilized in the study. Data triangulation was achieved by using more than one tool to collect the same data on different occasions, which gives the researchers multiple perspectives towards the studied population thereby providing a broader picture. Also, the study leveraged the benefit of prolonged involvement. The long-term relationship that already exists between the participants and researchers, who are both lecturers in Information and Communication Technology Department, enabled the investigators to understand how participants interpret terms used in the study and created an atmosphere of trust that ensured participants spent more time providing data.

Ultimately, the first phase of data collection involved the use of unstructured questionnaires to allow interviewees to articulate their thought unrestricted. Then followed by unstructured questionnaire with open-ended. The funnel interview model was adopted. With this model, the objectives of the interview were first presemted and the manner the data from the interview would be used was explained. Next, participants were asked open questions that then led to specific questions around cognitive and cognitive performance factors.

To ensure quality and engaging interaction and ease note-taking, the study population was partitioned into four focus groups and interviewed each group separately for 15-30 minutes. By interviewing each interviewee more than once, the researchers aim at gathering data that is both detailed and rich in context. The patterns that emerged from these interviews comprise the bulk of the data collected, transcribed, coded, and then qualitatively analyzed.

V. Discussion of Findings

From the data obtained, this study identified five cognitive predictors that influence students' performance in introductory programming. This discussion of this study's findings are, therefore, presented based these factors.

A. Academic Association

*T*his study revealed that most students believe that one's ability to associate academically with other students has a positive impact on academic achievements. The respondents strongly believe in the power of peers assisting each other. One respondent even went as far as starting, "I would not have pass intro. Programming but not for the support I received from my course mate who was very good in programming was my greatest nightmare – I felt like dropping out".

I can, therefore, be concluded that by helping one another in the classroom and outside of it, students are more likely to fully understand and remember the topics done in class, especially, in the concept of programming which often knew to most students. This is strongly supported by literature which states that students learn better when they interact as peers. The study conducted in [34] studied the impact of peers in mastering mathematics. The study concluded that peer learning facilitates the process of learning more effectively than a normal classroom. The effectiveness of peer learning was further lamented by the study conducted in [35]. Although the study came to the same conclusion, but also put a lot of emphasis on the effect of the environment rather than the association.

B. Cognitive Factors

Current literature widely alludes to the fact that self-belief positively impacts students' ability to execute tasks both in the classroom and outside. This finding also applies in the context of programming as this study equally supported this fact. Of the 20 respondents, 90% of them believed so much in the power of self-efficacy.

A study conducted in [28] found self-efficacy to be a powerful driver towards the ability to perform introductory programming. Studies in other fields equally corroborate this finding. For example, the work in [36], on people working on musical projects. The study concluded that employees with better self-efficacy performed well in musical projects than employees with low self-efficacy.

However, some respondents were of the view that self-efficacy alone is not enough to master programming. Some respondents thought that hard work should accompany self-efficacy for success to be guaranteed. On the other hand, some respondents viewed hard work as a product of self-efficacy. The belief was that once someone has a high self -efficacy, automatically they tend to be hard workers hence resulting in better performance. Apart from the fact that all respondents that performed extremely well in introductory programming were found to demonstrate the attitude of self-believe, some respondents noted that their performance only started to improve when they started believing that they too can learn programming.

Consequently, it can be infered that programming requires a lot of dedicated effort in the form of regular practice and self-efficacy is key to exercising such dedication. This also submission agrees with the study in [37], which concludes that self-efficacy is strongly correlated with hard work. According to the authors, there is a strong relationship between the level of self-efficacy and the effort that students.

C. Self-Drive to Work

The respondents frequently indicated that in the course such as programming, students need to put more effort into his or her work to get good results. They further alluded that students who usually perform better are those who spend most of their time working on solving programming problems in the labs or on their personal computers. Some respondents pointed to the laziness as an enemy of success in the computer programming course. This denotes that students who are given exercises in class and make little or no attempts are likely to perform poorly in the assessment that follows thereon while those who work hard are likely to do better. The study conducted in [26] examining the potential factors affecting student success is also in support of the view that the more effort a student puts on his/her work, the higher the chances of success in a programming course.

Hardworking was a commonly mentioned term by most of the respondents. They believe that a programming course by nature is practical. Thus, success requires one to be dedicated and learn by doing. The study revealed three concepts that have been used interchangeably by respondents, effort, hardworking, time spent on programming activities as having a significant influence on academic performance. These findings are in agreement with those of [27] who also found effort and hardworking to have a significant impact on academic performance. This is even though their study was examining these factors on the success in Mathematics. However, the majority of studies have shown a strong relationship between mathematics and computer programming due to their practical and problem-solving nature. It is therefore it bodes well to consider their argument about the findings of this study.

To improve student performance, the instructors must ensure that all students in the programming class are encouraged and monitored. Students should be monitored so that they do all their given class exercises or tutorials before given corrections as that will enforce everyone to practically learn.

D. Motivation

Motivation has been indicated in the literature to have a strong influence on academic performance and performance in the workplace. This study also revealed similar results. Motivation has been singled-out by almost all respondents as the key factor influencing one's academic performance. However, some respondents noticed that motivation does not directly influence academic performance. This is in line with the study conducted in [27]. The respondents enlightened that even the weak student if he or she is motivated is likely to succeed in programming. This is because the motivated individual has the drive to work hard and if one is motivated tend to never give up instead work even harder when faced with difficulties in the programming task. Even good students tend to perform poorly as the motivation diminishes.

The findings in [28] concluded that a high sense of self-efficacy tends motivating students to persevere. Furthermore, the authors also concluded that the increased perseverance results in the student putting more effort into programming.

The respondents also pointed out repeatedly that the reason for most of the students to drop out of the introductory programming course is when students fail the first few assessments resulting in them being demotivated. Theories of motivation support the view that performance decrease as the motivation decreases and increases as motivation increases.

There are two types of motivation, intrinsic motivation, and extrinsic motivation. This study further enlightened that extrinsic motivation is variable, tends to change, in the case of programming this type of motivation may change as difficulties and challenges arise during the course. The respondents also pointed out that self-motivation (intrinsic-motivation) is better than extrinsic motivation. While, self-motivated individuals who are also known as mastery-oriented individuals, they also tend to put more effort when the results are not in their favor.

E. The Love for Technology

Love of technology, and specifically, computer programming was frequently mentioned by most respondents, as influencing academic performance in computer programming. Studies that examined the relationship between computer game playing and success in programming advocate that students who like to play computer games are likely to succeed in programming. In this study found that students who love programming tend to be self-motivated and seek to understand than just doing it for the sake of obtaining a qualification. This type of students tends to be hard workers and always seek to find more information than what has been covered in the classroom. Such students spend time on YouTube video tutorials and other online materials hence find useful information on their own rather than in the classroom. Some respondents further stated that IT was not their preferred career path but decided to enroll for it because of desperation. These students were found to have very low self-efficacy of programming and put very little effort into their work. The work in [29] and [30] strongly argues that students who are doing courses that are not of their preferences tend to perform poorly.

VI. Conclusion

Educationists and educational psychologists have, for a long been investigating the factors that affect the performance of students. This paper explored the perception of students on the effect of cognitive factors on academic performance. The study aimed at addressing the challenge of underperformance in introductory programming course at a South African University of Technology. The findings of the the study showed that students strongly feel that cognitive factors have a significant impact on their performance. Whereas most studies seem to lay more emphasis on students' academic history, this study suggest that academic performance is influenced by a wider range of other interconnected factors. These findings have the potential to inform the design of a broad-based curriculum that incorporate both social and psychological components. Through such inclusions, performance inhibitors that stem from psychosocial factors can be addressed.

However, this study has limitations which are acknowledged as follows: geographically limiting the study to one institution as well as focusing only on ICT students may have effect in generalizing the results. Therefore, an investigation of more varied populations of universities and programs need to be conducted to improve the quality and validity of the results. That due to the delineation of this study, there was no comparative analysis with other similar methods. However, such an analysis has the potential to trengthen the possibility of generalization. Therefore, the future study from this work will focus on using existing frameworks to compare the methods adopted in this study to others in the current literature.

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Malware Analysis in Web Application Security: An Investigation and Suggestion

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***Abstract*—Malware analysis is essentially used for the identification of malware and its objectives. However, the present era has seen the process of malware analysis being used for enhancing security methods for different domains of technology. This study has attempted to analyze the current situation and status of malware analysis in web application security through some objectives. These objectives helps the authors to analyze the purpose, used methodology of malware analysis in web application security previously as well as authors select and find a prioritized technique of malware analysis through a hybrid multi criteria decision making procedure called fuzzy-Analytical Hierarchy Process. This fuzzy-AHP methodology helps the authors to find and recommend a most prioritized malware analysis techniques and type as well as suggest a ranking of various malware analysis techniques that used in web application security frequently for experts and developers use. Furthermore, second section of paper forecast the attack statistics and publication statistics of malwares and malware analysis in web application security respectively for understanding the sensitivity of topic and need of investigation. The proposed tactic intends to be an effective reckoner for web developers and facilitate in malware analysis for securing web applications. Additionally, the study also forecast the publication and attack scenario of malware and malware analysis for web application security that gives a complimentary overview of domain.**

Keywords—Malware analysis; web application; application security; fuzzy-AHP; forecasting

I. Introduction

Ever since the internet came into existence, its use has become expansive and ubiquitous. According to a report of the Internet World State in March 2019, “50.1% of the population in Asia uses the internet, 16.4% of the population uses the internet in Europe, 11.2% in Africa and 7.5% in North America [1]”. These statistics show a marked involvement and effect of internet on the life of people. Nevertheless, internet services also have their defined set of threats and risks. Unfortunately, there has been a massive increase in these threats in the recent years. Data statistics from anti-virus companies and security experts also show the rise of malware and cyber-attacks. Malware is one of the biggest threats for current web applications [2]. Easy accessibility of web is the biggest reason behind the rise of malware attacks against the web. Though the research domain in malware is increasing day by day, the number of attacks and attack-technologies are also increasing simultaneously.

Moreover, contending with these emerging attack-technologies has become a formidable challenge for the researchers and investigators in the field of malware analysis. Malware analysis is the process of determining the functionality, origin and potential impact of a given malware sample such as a virus, worm, Trojan horse, root kit, or backdoor. Defense against malware attacks is malware analysis. Malware analysis is the process of identifying, investigating and measuring the objective, functionality, and the harmful effects of any malware. Malware analysis is a combination of static and dynamic analysis methods. According to a testing lab survey, the success ratio of malware analysis is 96.67% [3]. There are many methods like API chaser, Sandboxing, Call graph method and others for providing accurate malware analysis result.

The focus of this Investigation is to summarize and review the previous research work that has been done on malware analysis and find a link for securing web applications through the malware analysis process. It is very important to analyze and classify the previous work done on securing web application through malware analysis properly for helping the future researchers. To the best of our knowledge, very limited work has been done on collating systematic literature reviews in the context of securing web application through malware analysis and other malware analysis related fields. This paper gives an overview of the previous research work done in the cited area and, further, it intends to help the researchers in identifying the areas where investigations need to be done more effectively for containing the harm done through malware attacks.

For facilitating an exhaustive investigation, the authors of this study have also classified malware attacks based on different categories, which have been further segregated into sub categories to explain the malware threats. Additionally, the study also categorize and prioritize various malware analysis methodologies through a scientific multi criteria decision making approach (MCDM) called fuzzy-Analytical Hierarchy Process (AHP). Fuzzy-AHP is a verified and effective approach for ranking and prioritizing. The use of fuzzy-AHP for ranking malware analysis methodologies can provide a view and idea to experts and researchers. The results of ranking experiment in proposed study will definitely beneficial for future research endeavors and authors believes that results can also be adopted by malware analysts in order to enhance the malware analysis techniques.

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Furthermore, The proposed study is constructed as the second section of study tells about the need of investigation through previous and future forecasted statistics of attacks and publications, then third section tells about the objective of study and fourth and fifth sections defines various experiments conducted by authors in order to achieve objectives. After that in next sixth and seventh section of study authors discuss and conclude the results and study, respectively.

II. Need of Investigation

Web applications and their security is the foremost concern in current digitalized world. Malwares are the most harmful threat actors for web application and most used vector for exploiting web applications. Authors of proposed study finds that malwares are the most used and effective threat vector against web application. Similarly, malware analysis is the only path for identifying and mitigating malwares in early stage according to various research and authors opinion. In order to understand the scenario of malwares against web application security authors find the previous cyber-attack tends against we applications and then forecast the possible growth for future years in malware attacks through a forecasting tool called GMDH Shell DS [4].

Fig 1 discusses the previous and future statistics of malware attack based on an online study [5-7]. The attack ratio shown by the authors in Fig. 1 tells that the condition of malware attacks is highly critical and the future statistics of attacks (based on previous datasets) show that the situation is going to be worst in the next 5 years.

After identifying the scenario of attacks and forecast it authors try to understand the research scenario also for analyzing the research ratio against the attack because the attack situation clearly represent that there is need for a solid and unified solution against malwares in web application security. Due to this need it is important for authors to understand the research condition of malware analysis in web application security. For achieving this goal authors select only quality databases and research articles that pose a contribution in web application security as a malware analysis technique. In order to analyze previous researches authors find following counts and forecast these previous statistics for next five years to understand the future scenario also.

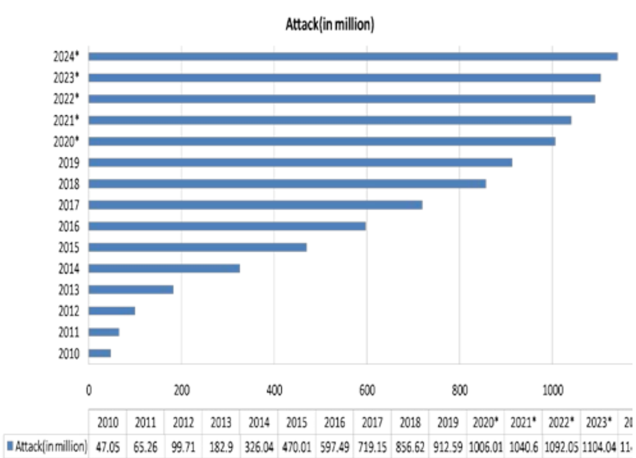

Fig. 1. Previous and Future Attack Ratio.

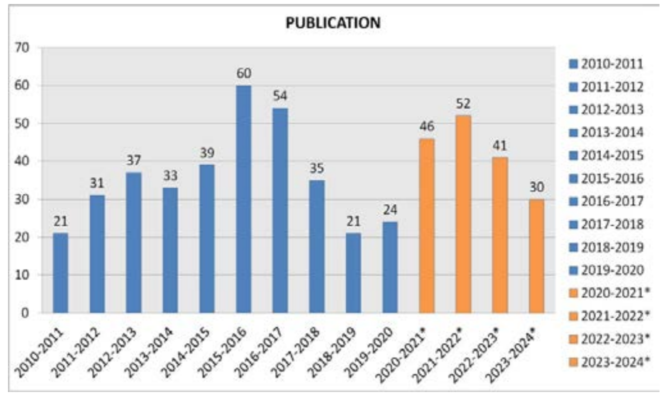

Fig. 2. Previous and Future Forecasted Statistics of Research Publications.

The ratio of previous and future forecasted data is not very different and clearly represent that it is not sufficient for web application security against malwares in the comparison of attack trends that is discussed in Fig. 1. Authors strongly believe that there is need for more research publications and research endeavors. These statistics and forecasted ratio of attacks and publications motivate authors to investigate the malware analysis in web application security with some universally adopted and effective objectives. In order to understand the objectives authors discuss about them in next section.

III. Investigation Objective

Every investigation has their objective. These objectives are the goals that are achieved by investigator or a researcher during the whole analysis process. In the context of this study, authors have two main and significant objectives. These objectives are described below:

Objective 1: Why and which malware analysis process is used in previous research in order to secure web applications?

Motivation: Malware analysis is a process that is normally used for identifying malwares or malicious activities after the harm is done in system. But in current situation from some previous year's malware analysis techniques are used for variety of works and security mechanism from different types and attributes. Authors choose this objective just because there is need to associate and summarize the whole previous scenario of malware analysis as a security approach for web application in one place.

Objective 2: Which approach plays a key role as an effective technique of malware analysis that helps the future researchers as a research topic or development idea?

Motivation: Authors aim is to provide a systematic prioritization wise list of various malware analysis techniques to effectively help the experts and researchers. A prioritization method effectively contributes in malware analysis research. Selection and prioritization of techniques can provide step wise path to developers and experts in order to secure web application.

Further, for achieving these two objectives authors performed condition examination and ranking examinations that are described and discussed in next sections.

IV. Condition Examination

This type of examination is introduced by authors to analyze and review the current situation of malware analysis in web application security perspective. During this type of examination authors identify the various aspects of malware analysis in previous web application security research with malware analysis. Various sub-assessments that are performed by authors are written below:

A. Purpose Analysis

The main goal of this analysis is to identify the purpose of use of malware analysis in web application security. This type of analysis can provide some effective and crisp analyzed information regarding malware analysis as well as its use. These objectives or purposes will help the prospective researchers and practitioners to find the purpose of malware analysis and the need for malware analysis for web application security. Malware analysis targets objectives like Cyber-attacks, privacy harm and several others in previous research initiatives. Additionally, in this type of analysis authors find following objectives or purpose of malware analysis for web application security.

Cyber Attacks: Recent experiences of web applications services show that cyber-attacks are the foremost focus of many research publications. Malwares are the primary and mostly used source of any cyber-attacks. Malware analysis approaches provide a path for experts and researchers to provide a prevention mechanism for them. The model given by GuozhuMeng [8], in May 2018, is probably the most accurate approach for addressing this issue. In this model, the combination of security analyst approach and web security works properly for securing Android app market from harmful malicious apps. There are other papers [9, 10] which also discuss the challenges and threats of malware as cyber-attack. These papers [9, 10] provide a deep need of malware analysis by raising the malware issue as the biggest threat for web applications.

Harm on Privacy: Privacy on the web applications is the most pertinent issue for any user and is rated as the top priority by all service users. Harm on privacy objective shows that malwares are rapidly targeting web applications and the biggest challenge for experts now is in privacy issues [11].

Network Security: Malware has emerged as a potent weapon for the attackers and in today's scenario, the attackers use malware in almost every place for exploit. Aziz Mohaisen has proposed a method of malware detection in a network by using artifact behavior analysis [12]. This approach includes static analysis automated tool technique for better results and less consumption of time.

Enhancing Malware Analysis: Many researchers use different types of methodologies and hybrid methods for enhancing malware analysis procedures. Igocio Martin has proposed a machine level approach for android signature-based malware detection [13].

B. Technique Analysis

This section is an important part of investigation. In order to analyze the used various techniques of malware analysis in web application security authors conducted an in-depth analysis of previous researches to gauge the analyzed solution. The findings related to malware analysis methods have been categorized into different parts by the authors. In the process of assimilating the findings from the publications, authors found two classic malware analysis methods; i.e. Behavior-based Analysis and Signature-based Analysis. These methods are used by the experts and researchers for facilitating malware analysis methodology in their paper. Table II shows the approaches that have been discussed as follows:

Behavior-based Identification: Behavior-based malware analysis is the most used methodology by previous researchers. In the process of behavior-based analysis of malware the tool or technique analyze and examine the behavior of commands, code work-flow and network traffic, etc. [14-18]. This type of methodology is effectively used in current era of malware analysis. Behavior-based analysis techniques that are used in web application security through previous researchers are described following:

Machine Level Approaches: In this part, the authors found papers discussing the same approaches with different methods for their different objectives. A Mohaisen talks about antivirus malware identification methods with the help of machine level method for better results [19]. There are many other papers [20, 21, 22] related to machine level approaches for identification, classification, and analysis of malware. Table II combines the approaches with the application of research papers.

Sandboxing (API Chaser): In this part, the authors have included the papers that discuss the dynamic methodology of analysis. Sandboxing is a tool-based identification methodology that analyzes the API calls of a particular program. Yuhi Kawakoya proposed a method of sandboxing technique to analyze malicious application [23]. The taint coding methods have also been used for identifying malicious code sliding in API calls. The method is an effective approach for identification of malware. There are many other papers, at present, that discuss the sandboxing approach in different ways for performing malware analysis [24, 25].

Network Traffic Analysis: In this sub-section, the authors have discussed about several research papers based on network traffic analysis method for identifying malware artifacts. Network traffic is a collection of incoming and outgoing connections which help an examiner to collect footprints and essence of malware. XiaolinGuiet et al. has proposed a model XcodeGhost [26]. According to Gui, the model can find the ratio of infection devices and categorize the characteristics of malicious application traffic for analysis purpose.

Signature-based Identification: Authors of this study found that less number of studies and researchers are using or adopting signature-based malware analysis into the comparison of behavior-based analysis or identification. Signature-based analysis of malwares is the process of identifying malicious attributes from comparing previously identified and stored attribute or file [14]. But on the other hand, as per the Table II, it is also evident that signature-based analysis of malwares are adopted as well as used for achieving every objective in previous research initiatives. This study has analyzed the previously used main techniques for signature-based identification under the following headings.

Artifact Ordering: In this part, the authors included those papers which discussed the static analysis approaches based on artifact analysis. Aziz Mohaisen proposed a paper discussing network traffic analysis based on artifact ordering [12]. An author of one research study has also proposed a model for analysis with the help of autosomal and n-gram feature extractor. There are many other papers that have discussed the static analysis approaches and artifact analysis features [27].

Virus scan/Comparing previously identified malicious signatures: In this sub-section, the authors have discussed about different signature-based approach papers that have been used by previous researchers for better malware analysis process [28]. The signature-based method is a static analysis approach for analyzing malware. Cristian Adrián Martínez et al. have discussed the signature based mechanism of malware detection in cloud environment [29]. Cristian proposed a model uCLAVS that has some predefined set of protocols based on previous malware signatures and actions. The model efficiently collects the malicious activity information and with the help of IDS (Intrusion Detection System) notifies about the harmful activity.

Portable Executable file analysis: PE file analysis is a process of analyzing executable files for the possibility of malicious attribute in it. It is a signature-based identification process that compares the PE header with previous malware signatures for identifying the malicious attributes of file.

Reverse Engineering: Reverse engineering is a type of method that is use as a last option by many malware examiners. It is a process where examiner chose the software engineering approach called reverse engineering for disassemble the code and analyze the whole code I reverse order node by node for deep and exact identification of malicious activity. Reverse engineering is a lengthy but effective process for malware identification with static analysis attributes. Extracting malicious activity of code or application from low level of language analysis and examination is most effective quality of reverse engineering that makes it an effective approach. Further, authors also find that reverse engineering is not a part of classical malware analysis methodology it is added after the hybrid malware analysis approach came into existence in modern malware analysis methodology.

V. Ranking Examination

Ranking examination is a process that is adopted by authors to select and find an effective and prioritized malware analysis technique list with a most prioritized malware analysis approach for developers and experts. Previously, authors discuss about various malware analysis techniques that are effective and useful additionally, in order to construct a hierarchy of malware analysis techniques authors examine the malware analysis process and find that before discussing the techniques of malware analysis there is a classification of malware analysis types that is one of the most significant and effective part of malware analysis process [30]. Further, it is important to discuss about these types before constructing a tree like structure of malware analysis techniques. Descriptive descriptions of various types of malware analysis are:

The authors have categorized and calculated the overall percentage of three basic types of malware analysis for better and easy understanding. This type of categorization will help the readers to easily comprehend the trend and functionality of the malware analysis research related to web applications. This categorization also provides an overall percentage classification of basic malware analysis types. Fig. 3 describes the percent ratio of a malware analysis types through the previous research initiatives.

Static Analysis: Static analysis is the most useful identification mechanism for malware and manual static analysis of a malicious code (If possible) is the first approach that a researcher takes in any kind of malware identification. In the process of classification, the authors found that 30% of the papers are based on static analysis approaches. For example, a method of Application Security Triage (MAST) helps in malware selection by statistical analysis approach [31-35]. The authors of this SLR also found similar static analysis studies that proposed a better research environment.

Dynamic Analysis: In this sub-section, the authors have included research publications that have discussed the dynamic malware identification approach and detection methodology for web applications or can be useful for web applications. Dynamic approach of analysis is automated computerized technique for analyzing malware. At the categorizing period, the authors found that 34% of the papers talked about dynamic analysis approach [36-40]. Moreover, many dynamic analysis papers that are available discuss about the vulnerabilities of dynamic mechanism. For example, Katsunari Yoshioka et al. have discussed the vulnerability of public sandboxing analysis system in [41-45]. Katsunari has discussed that public sandboxing system enables remote host service for updating and alteration in analysis during the examination from the company's end but this service can cause high risk. K.Y. provides a solution for this kind of vulnerability by dynamic IP addressing.

Hybrid Analysis: During the classification of basic malware analysis approaches, the authors found quite a few papers that discussed about the combination of static and dynamic analysis. In fact after gauging several publications, it was obvious that Hybrid analysis was the most accepted analysis technique for several researchers [42-45]. The share ratio of publication is 36 % for hybrid analysis in types of malware analysis approaches. The hybrid analysis includes hardware and software combination also, like Das S et al. delivers hardware for malware detection online [46]. Das proposed an embedded system by combining the processor and FPGA. The aim of hardware is to capture the behavior of malware and detect it online.

Furthermore, now after discussing the types of malware analysis approaches authors construct the hierarchy of various types and techniques of malware analysis by summarizing and associating all the techniques under one roof. Authors develop a hierarchical figure of malware analysis techniques and types that is described in Fig. 4.

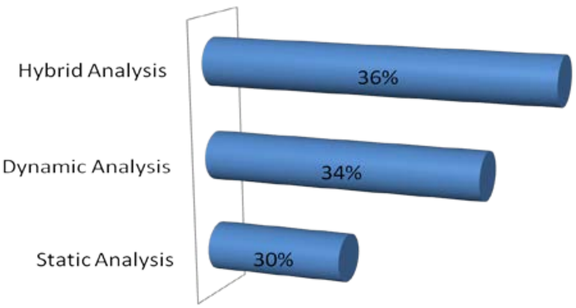

Fig. 3. Percentage Contribution of Various Types of Malware Analysis Types According to Current Trend.

Fig. 4 represents the whole malware analysis types and techniques that are used for securing web applications. Authors apply a multi criteria decision making (MCDM) approach called fuzzy- Analytical Hierarchy Process (AHP) for evaluating the priority and finding the most prioritized approach and type of malware analysis [46-52]. Fuzzy-AHP is methodology that is pre-verified and authors has expertise in fuzzy-based various MCDM approaches through their previous experience [53-56]. Fuzzy-AHP methodology works on triangular fuzzy numbers and provides some crisp and effective outcomes [57-61]. Authors strongly believe that fuzzy-AHP is the most promising and effective technique for assessing the priority of malware analysis techniques and types.

A. Numerical Assessment

Numerical assessment of malware analysis types and techniques from fuzzy-AHP methodology is associated with the inputs of 70 experts from industry and academic that is taken by authors for evaluation process. Further, after collection of suggestions authors apply the fuzzy-AHP technique on layered Fig. 2 and find the following pair wise comparison matrix that is defined in Tables I to IV [62-66]. Now after, successful construction of pair wise comparison matrix of every layer and malware type and technique authors apply defuzzification of calculated weights in pair wise comparison matrix through adopted fuzzy-AHP methodology [67-71]. Table V to Table IX shows the defuzzification of local weights and their associated dependent weight. Final ranking of sub-factors are displayed in Table X.

Above Table X represents the calculated weights and their associated ranking of various malware analysis techniques and types that are described in Fig. 2. The result discussed in Table X clearly describes that hybrid analysis and its second layered attribute dynamic + static analysis (combined) has most priority and rank in all the malware analysis techniques. Similarly, the Table X represents the various ranking list of malware analysis techniques that can be utilized and adopted by developers and researchers for producing effective and useful malware analysis techniques and approaches that enhance the web application security more frequently.

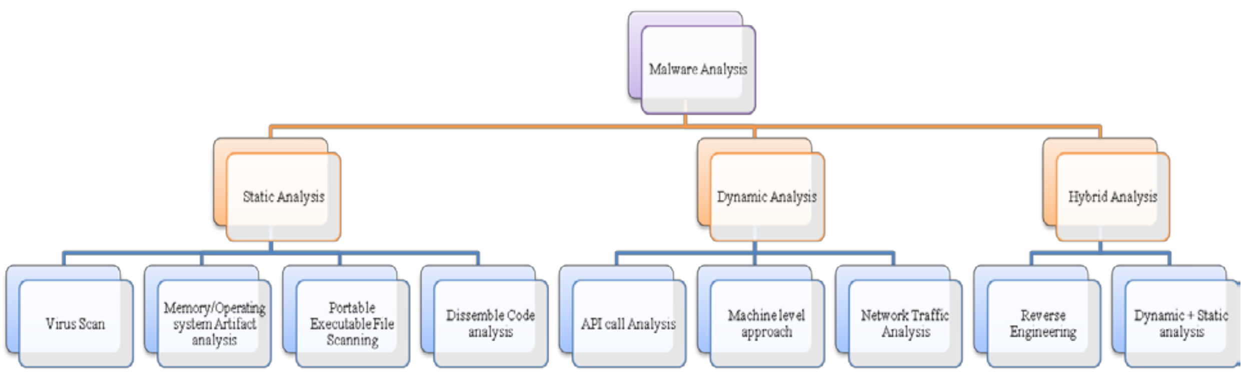

Fig. 4. Hierarchy of Malware Analysis.

TABLE I. COMPARISON MATRIX FOR LEVEL 1 OF FIGURE 4

	Static Analysis (R1)	Dynamic Analysis (R2)	Hybrid Analysis (R3)
Static Analysis (R1)	1.00000, 1.00000, 1.00000	0.40670, 0.54970, 0.78760	0.49560, 0.70290, 0.93300
Dynamic Analysis (R2)	-	1.00000, 1.00000, 1.00000	0.79120, 0.88310, 1.02040
Hybrid Analysis (R3)	-	-	1.00000, 1.00000, 1.00000

TABLE II. COMPARISON MATRIX FOR LEVEL 2 FOR R1 OF FIGURE 4

	Virus Scan (R11)	Memory/OS artifact analysis (R12)	PE file analysis (R13)	Dissemble code analysis (R14)
Virus Scan (R11)	1.00000, 1.00000, 1.00000	0.55980, 0.89940, 1.37050	0.48760, 0.67100, 0.89000	0.38360, 0.54830, 0.83440
Memory/OS artifact analysis (R12)	-	1.00000, 1.00000, 1.00000	0.80010, 1.23760, 1.78120	0.27700, 0.38540, 0.63400
PE file analysis (R13)	-	-	1.00000, 1.00000, 1.00000	0.59660, 0.70930, 0.90950
Dissemble code analysis (R14)	-	-	-	1.00000, 1.00000, 1.00000

TABLE III. COMPARISON MATRIX FOR LEVEL 2 FOR R2 OF FIGURE 4

	API call Analysis (R21)	Machine level Analysis (R22)	Network Traffic Analysis (R23)
API call Analysis (R21)	1.00000, 1.00000, 1.00000	0.55060, 0.58810, 0.66470	0.22550, 0.27620, 0.35740
Machine level Analysis (R22)	-	1.00000, 1.00000, 1.00000	0.68980, 0.88600, 1.10020
Network Traffic Analysis (R23)	-	-	1.00000, 1.00000, 1.00000

TABLE IV. COMPARISON MATRIX FOR LEVEL 2 FOR R3 OF FIGURE 4

	Reverse Engineering (R31)	Dynamic + Static Analysis (R32)
Reverse Engineering (R31)	1.00000, 1.00000, 1.00000	0.30510, 0.38920, 0.56090
Dynamic + Static Analysis (R32)	-	1.00000, 1.00000, 1.00000

TABLE V. COMBINED MATRIX FOR LEVEL 1 OF FIGURE 4

	Static Analysis (R1)	Dynamic Analysis (R2)	Hybrid Analysis (R3)	Weights
Static Analysis (R1)	1.00000	0.57340	0.70860	0.241684
Dynamic Analysis (R2)	1.74400	1.00000	0.89450	0.378445
Hybrid Analysis (R3)	1.41120	1.11790	1.00000	0.379871
C.R.= 0.00580878				

TABLE VI. COMBINED MATRIX FOR LEVEL 2 FOR R1 OF FIGURE 4

	Virus Scan (R11)	Memory/OS artifact analysis (R12)	PE file analysis (R13)	Dissemble code analysis (R14)	Weights
Virus Scan (R11)	1.00000	0.93230	0.66470	0.57870	0.184502
Memory/OS artifact analysis (R12)	1.07260	1.00000	1.26420	0.42050	0.211198
PE file analysis (R13)	1.50440	0.79100	1.00000	0.73040	0.233061
Dissemble code analysis (R14)	1.72800	2.37810	1.36910	1.00000	0.371239
CR= 0.0237475					

TABLE VII. COMBINED MATRIX FOR LEVEL 2 FOR R2 OF FIGURE 4

	API call Analysis (R21)	Machine level Analysis (R22)	Network Traffic Analysis (R23)	Weights
API call Analysis (R21)	1.00000	0.59790	0.28390	0.168952
Machine level Analysis (R22)	1.67250	1.00000	0.89050	0.348472
Network Traffic Analysis (R23)	3.52240	1.12300	1.00000	0.482576
C.R.= 0.0220487				

TABLE VIII. COMBINED MATRIX FOR LEVEL 2 FOR R3 OF FIGURE 4

	Reverse Engineering (R31)	Dynamic + Static Analysis (R32)	Weights
Reverse Engineering (R31)	1.00000	0.41110	0.291333
Dynamic + Static Analysis (R32)	2.43250	1.00000	0.708667
C.R.=0.000000			

TABLE IX. CALCULATED FINAL WEIGHTS

Main	Local Weights	Sub	Local Weights	Dependent Weights
R1	0.241684	R11	0.184502	0.044591
		R12	0.211198	0.051043
		R13	0.233061	0.056327
		R14	0.371239	0.089723
R2	0.378445	R21	0.168952	0.063939
		R22	0.348472	0.131877
		R23	0.482576	0.182629
R3	0.379871	R31	0.291333	0.110669
		R32	0.708667	0.269202

TABLE X. OVERALL WEIGHTS AND PRIORITIES

Sub- Regions	Weightages	Percentages	Overall Ranks
R11	0.04459	4.45%	9
R12	0.05104	5.10%	8
R13	0.05633	5.63%	7
R14	0.08972	8.97%	5
R21	0.06394	6.37%	6
R22	0.13188	13.18%	3
R23	0.18263	18.26%	2
R31	0.11067	11.06%	4
R32	0.26920	26.92%	1

VI. DISCUSSION AND LIMITATION

This section is totally dedicated for assessing the objectives of the investigation that leads the authors to conduct the examination of previous research from various point of views.

A. Assessment of Objective 1

Objective 1 of authors is totally dedicated to find and summarize the current status of malware analysis techniques in web application security based on why and how they are. In order to find and achieve the objective 1 author conduct the purpose analysis and technique analysis to find why and how the malware analysis approaches are applied in web application security previously. These analysis sections clearly represent the status and used techniques associated with their objectives or purpose in web application security. Following Table XI represents the techniques and the associated purpose of malware analysis use in web application security for presenting a systematic view on the situation of malware analysis techniques and its purpose of use in web application security.

After evaluating the situation of malware analysis as a security approach for web applications authors find some following attributes and challenges of malware analysis types and techniques.

Security will remain a strong focus for malware analysis: Malware analysis for web security is the main topic of this SLR. As per the findings of the authors, statistics and data show that research trends are focusing on the security aspect of the web, Android and other relevant areas of computer. For example, Brandon Amos et al. has proposed a technique by combining machine learning and dynamic analysis approach for better detection of malware online[47, 72-74].

Minimum number of related articles and research endeavors: The authors found that there is no SLR on malware analysis for securing the web application, though there were many other surveys that discussed other related domains like-the static analysis, dynamic analysis of malware and malware detection survey and others. One of the examples in this context is that of Rami Sihwail et al. The study provides a brief discussion on current malware analysis techniques [48], classification of malware in the current situation and also provides literature about different kinds of malware detection methods. There are some other related papers present in the study [49, 50, 75].

The need for Controlling Malware attacks: After studying all the relevant publications and articles, it is evident that the malware attacks are the biggest threat to web security and there is an imminent need of a good malware analysis procedure that can reduce the threat of malware attacks in web applications.

B. Assessment of Objective 2

Second objective of authors is to select and suggest a prioritized malware analysis technique for future use and development in web application security. Additionally, for achieving this goal authors adopt the methodology fuzzy-AHP for evaluating the priority of various malware analysis techniques and types that are identified by authors through their first objective. A prioritization approach is performed by ranking examination section in the paper. Further, after a successful implementation of ranking examination authors find the following result:

Hybrid Approach produce better result: After an intensive analysis of the papers, the authors found that a hybrid approach of malware analysis mechanism is a key for better results in web application security. Many researchers are focusing on the hybrid malware analysis technique in their research endeavors. The hybrid approach opens the door for researchers to use static and dynamic methods at the same time as a combination. This combination increases the possibility of malware detection as well as decreases the threat ratio for web applications. One of the relevant examples in this context is that of Shahid Alam et al.'s study that proposed a framework for metamorphic analysis mechanism for real-time detection of malware [52]. Metamorphic malware analysis is based on binary code analysis, a part of dynamic analysis that uses a static approach in the identification of old malware.

In simple words the framework uses a combination of dynamic and static malware analysis in a unique way for producing effective malware detection. The authors of this study have also extracted some other papers [76, 77, 51, 53, 27, 8, 15] that have delivered hybrid approaches for better results. Moreover for providing more convincing discussion on this topic, the authors of this study have comparatively analyzed all three malware analysis approaches. Table III illustrates the comparative study. The results of comparative study clearly portray that dynamic and static malware detection have shortcomings in their own environment. However, a hybrid approach overcomes those lacunae by providing extremely effective detection ratios.

For example, sometimes it is crucial to run the malicious file without understanding the malware class and its behavior during the run stage [30]. During this period of analysis, the hybrid approach provides a static detection of malware class from its static analysis and at the same time malware analyst prepares the analysis environment according to the result of static analysis for further dynamic analysis. Such an approach facilitates a secure and accurate success ratio in malware analysis process.

Further to help and motivate the analyzed outcome of investigation authors performed and present a comparative study of static, dynamic and hybrid malware analysis techniques based on some standards that are defined by [30] in Table XII.

TABLE XI. APPROACHES THAT HELP THE OBJECTIVE

	Approach	Attack	Harm of Privacy	Network based Security	Enhancing Malware Analysis
Behavior-based Analysis	***Machine level***	✓	✓		✓
	Sandboxing (API Chaser)		✓	✓	✓
	Network Traffic Analysis	✓	✓	✓	✓
Signature-based Analysis	***Artifact Ordering***			✓	
	Virus Scan	✓	✓	✓	✓
	Portable Executable file analysis	✓	✓	✓	
Reverse Engineering		✓	✓	✓	✓

TABLE XII. COMPARATIVE STUDY OF MALWARE ANALYSIS TECHNIQUES

Analysis Techniques/Parameters	Condition (Mode) of malware at the time of analysis	Consumed time in analysis process	Effect of anti-malware analysis tools & techniques	Extracted information from analysis process
Static Analysis	At Rest Mode	Usually less through static analysis tools.	Normally anti-detection techniques can easily bypass or hide their malicious attribute from static analysis.	Very less and low in impact.
Dynamic Analysis	At Running mode	Usually more time consumed due to activated or running motion of malware.	Normally need more advance anti-detection tool or technique to bypass the dynamic analysis because of its running motion nature.	Highly informative and extract useful information.
Hybrid Analysis	Both (At rest and run mode)	More time taking into the comparison of static analysis and dynamic analysis.	It is most challenging and critical task for anti-detection tools and techniques to bypass or tackle the hybrid analysis due to its hybrid (Static detection + Dynamic detection) nature.	Provide a perfect blend of useful information associated with risk factors and its approximate impact.

VII. CONCLUSION AND FUTURE WORK

Research on malware analysis for web security is rapidly maturing. This research endeavor specifically focuses on the current status or situation of malware analysis in web application security and tries to suggest a malware analysis technique and priority ranking of various malware analysis techniques that helps in web application security through fuzzy-AHP method. The investigation itself has several defined and categorized procedures for tabulating the situation of malware analysis based on previous research endeavors. As per the results discussed in the above sections, the following possible directions for future work can be envisioned:-

First: A good and effective malware analysis procedure has to be employed for controlling malware attacks and losses of enterprises. Malware analysis is the only way for understanding malware and their respective objectives. However, there is a gap between malware and malware analysis procedures. There is no systematic framework available for malware analysis and for securing web applications specifically.

Second: The outcome of the research work done on malware, as of now, is not effective and practical. Practically possible implementations are needed for malware analysis field in securing web application. There is a huge gap between malware analysis approaches and web application security that needs to be filled.

Third: The authors also found that the old web application security mechanisms are not totally updated in regular mode in many organizations. A validated process for securing web application through malware analysis is strictly required from the perspective of security. A deep analysis between different malware analyses approaches are recommended for producing an effective work flow for web application security by the authors.

Fourth: The proposed research review only provides a critical view on current malware analysis mechanisms that are used and adopted by web application security practitioners. Finding various defense mechanisms and integrating defense scenario with current mechanism trends is the research possibility for future initiatives. Our SLR has cited several studies on defense strategies like access control mechanisms, encryption and cryptography, etc. which could be a premise for further research investigations.

This study conclusively asserts the situation and suggestion for malware analysis to ensure optimum web application security. The research Endeavour tries to fill the gap between malware analysis approach and web applications by providing a snap of its status and suggest a path through a scientific verified methodology. The authors reiterate that a systematic malware analysis framework in web application security perspective can enhance the security mechanism of web applications and reduce the attack rates of the malwares.

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Lightweight Security Mechanism over MQTT Protocol for IoT Devices

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***Abstract*—Security is one of the main concerns with regard to the Internet of Things (IoT) networks. Since most IoT devices are restricted in resource and power consumption, it is not easy to implement robust security mechanisms. There are different methods to secure network communications; however, they are not applicable to IoT devices. In addition, most authentication methods use certificates in which signing and verifying certificates need more computation and power. The main objective of this paper is to propose a lightweight authentication and encryption mechanism for IoT constrained devices. This mechanism uses ECDHE-PSK which is the Transport Layer Security (TLS) authentication algorithm over Message Queuing Telemetry Transport (MQTT) Protocol. This authentication algorithm provides a Perfect Forward Secrecy (PFS) feature that makes an improvement in security. It is the first time that this TLS authentication algorithm is implemented and evaluated over the MQTT protocol for IoT devices. To evaluate resource consumption of the proposed security mechanism, it was compared with the default security mechanism of the MQTT protocol and the ECDHE-ECDSA that is a certificate-based authentication algorithm. They were evaluated in terms of CPU utilization, execution time, bandwidth, and power consumption. The results show that the proposed security mechanism outperforms the ECDHE-ECDSA in all tests.**

Keywords—Internet of Things (IoT); MQTT; Pre-Shared Keys (PSK); elliptic curve cryptography; Diffie-Hellman Ephemeral (DHE); Digital Signature Algorithm (DSA); Perfect Forward Secrecy (PFS); authentication; power consumption; wireless sensors

I. Introduction

The Internet of Things (IoT) has been developed significantly and is moving towards maturity. It can be viewed as “a global network which provides the communication between human-to-human, human-to-things, and things-to-things by making a unique identity for each object” [1]. Multiple objects which include embedded sensors, wireless communication, processors, can be linked together to make the network of IoT. The Internet of Things is a mixture of two terms. The first term is the Internet, which connects billions of users, devices, personal systems, and even business organizations. The second term is Thing, which refers to intelligent objects [2].

There are many different environments [3] where IoT objects interact automatically with their surroundings and the Internet automatically and independently, as a result, a lot of security and privacy concerns have arisen. IoT devices have become crucial to many enterprises and even cities and preserving exchanged data becomes most important. Also, objects in IoT networks are seriously resource-constrained with limited computational ability, memory, and power, so it is very difficult to implement heavy operations on them which are required by ciphering algorithms. They need a lightweight security mechanism with low resource consumption. Traditional authentication and encryption methods have a huge overhead on IoT devices. Therefore, this study focuses on the evaluation of a lightweight security mechanism that secures communication in IoT networks as well as reduces resource consumption of IoT limited devices.

Based on these requirements in IoT networks, a communication stack is needed to provide a low-power, secure, and lightweight protocol. IoT communication stack includes different types of protocols [4] [5], this paper was tried to improve the security of the MQTT application layer protocol since it built on top of TCP protocol, has low power usage and lightweight overhead than other IoT protocols [6]. In addition, because IoT networks depend on TPC/IP, in this study, Transport Layer Security (TLS) [7] is selected which is the reliable protocol and supports most of the security cipher suites. Then the TLS evaluated over MQTT protocol when using the ECDHE-PSK authentication algorithm. The results are then compared with the ECDHE- ECDSA and also with the default security mechanism of the MQTT protocol.

The rest of the paper is categorized as follows: Section II reviews previous works related to IoT security also an overview of the MQTT protocol. Section III provides details of the proposed security mechanism. Section IV describes performance evaluation and discussion on the results. Lastly, Section V concludes the paper and offers a suggestion for future work.

II. Related Work

A. Message Queuing Telemetry Transport (MQTT) Protocol

MQTT is an open protocol, standardized by OASIS and became an ISO standard (ISO/IEC 20922:2016) [8]. This protocol is being adopted widely and used extensively by most big companies such as Amazon and Facebook to exchange data between resource-constrained devices. MQTT supports publish/subscribe architecture [9] over TCP [10] protocol. It has two components that are the client as a publisher or subscriber and the broker. The publisher publishes messages and the client subscribes to certain topics that are relevant to them and by that, receives every message published under those topics. Each message has a topic and clients can subscribe to several topics. These topics categorized in a hierarchical system [11] similar to file paths in a computer; e.g. “home/living room/air condition/status”.

MQTT has a low overhead, meaning that it sends a very small amount of extra data and the actual content of the message. The MQTT header is incredibly small (only 2 bytes) [12] in comparison with other protocols like HTTP or CoAP [13].

Among different IoT protocols the Quality of Service (QoS) [14] features of MQTT make it unique which guaranteed delivery of messages and assurance of data distribution between two parties.

MQTT has default security features [15], For instance, for authenticating purposes, MQTT offers a simple authentication method via username and password for connecting a client to the broker. Authentication options are sent in plaintext without any encryption. Therefore, developers can implement their own security mechanisms on the network and transport layer. Security can also be provided at lower layers. For instance, MQTT uses TLS on the Transport layer to protect communication between parties.

B. The Transport Layer Security (TLS) and its cipher suits

TLS protocol [16] is a widely used secure-channel protocol that allows secure end-to-end communication between two devices. It utilizes cryptography for data protection and device authenticity. This protocol contains two main protocols: the TLS handshake protocol and the TLS record protocol. The handshake protocol allows the client and server to authenticate each other and to negotiate an encryption algorithm, MAC algorithms, and session keys for data encryption in the TLS record [17]. The TLS Record Protocol secures the connection after the TLS Handshake Protocol established using symmetric cryptography such as RC4 or AES [18] and hash functions like SHA-1 [19]. The operation is determined by the cipher suite which applied and its name represents the involved algorithms. For example, the TLS-ECDHE-ECDSA-CHACHA20-POLY1305-SHA256 cipher suite uses ECDHE as the key-exchange algorithm, ECDSA as the authentication algorithm, CHACHA20-POLY1305 as the stream cipher, and SHA256 as the hash algorithm to preserve message integrity of the handshake process.

There are some alternatives for securing end-to-end communications in networks with resource-constrained devices. For instance, using a protocol like Datagram TLS (DTLS) [20] was suggested in the past. It was developed to secure UDP-based protocols such as CoAP. It was originally developed to protect web application communication and its executions have heavy overhead [21] in IoT networks. Further, DTLS implementation is complex since it works on top of the UDP protocol. Since DTLS using UDP as a transport protocol, it cannot ensure reliability as much as TLS can, although it employs a “sequence number” field for verification. Furthermore, DTLS is not resistant against Denial of Service (DoS) attacks [22]. As a result, the use of (TLS) is becoming compulsory for most of the communications since it provides a better security level.

C. Elliptic Curve Diffie Hellman Ephemeral (ECDHE) Key exchange algorithm

ECDHE is an algorithm used for key exchange which lets two entities to make a shared secret. In fact, it is an adaption of the Diffie-Hellman (DH) [23] key exchange protocol that employs elliptic curve cryptography to minimize the key length and improve performance. Elliptic curves are used widely in various key exchange methods which include the DH key agreement. ECC [24] provides a security level similar to RSA but with smaller key sizes [25] that result in fast calculations and less power consumption for IoT devices.

In the ECDHE algorithm, each party must generate a key pair (include a public key and a private key). Public keys are Ephemeral therefore a unique session key made for each session and provide the Perfect Forward Secrecy (PFS) [26] feature. This feature guarantees that the session keys will not be compromised by making a unique session key for each session. Previous key exchange algorithms like RSA [27] and ECDH [28] cannot provide the (PFS) feature because of their static public keys. There are some papers that compared RSA and ECDH-based cryptography together. According to measurement results in [29], the overall execution time of TLS-ECDH is faster than TLS-RSA. In [30] the power consumption and performance of RSA, DH, and ECDH key exchange algorithms are compared and the results showed the ECDH algorithm is better than others. Although ECDH outperforms RSA and DH algorithms, it cannot provide forward secrecy feature that is possible by using ECDHE algorithm.

D. Elliptic Curve Digital Signature Algorithm (ECDSA) Authentication algorithm

The U.S. National Institute of Standards and Technology (NIST) developed the Digital Signature Algorithm (DSA) [31] for use in their Digital Signature Standard (DSS) in 1991. In a Digital Signature, the signer's Private Key is used to sign, and the signatory's Public Key is used to verify the signature by the recipient. The ECDSA [32] is an elliptic curve variant of the DSA algorithm that produces cryptographically digital signatures by using the Elliptic curve. This algorithm applies (160/256 bits) which is much smaller rather than (1024/2048 bits) in DSA and RSA [33]. In [34] they considered ECDSA performance compared with RSA and concluded how employing various ECC curves and also RSA key sizes impact energy consumption in IoT nodes. The results showed that ECDSA was better than RSA to secure IoT communications with resource-constrained devices since RSA has large key sizes. Although ECDSA eliminates the issues of RSA and DSA algorithms, its resource consumption is still high for IoT resource-constrained devices due to signing and verifying the certificate.

III. Proposed Security Mechanism and Experiments

Security in IoT networks is the main concern for developers. Since most IoT nodes are limited in resource and power, they require a security mechanism that fits their limitations. This research provides a lightweight security mechanism for IoT resource-constrained devices over the MQTT protocol.

Previous authentication methods (like RSA and ECDSA) use a certificate to authenticate devices. Although using a certificate provides a high level of security, signing and verifying certificate uses a high computational process that increases CPU and power consumption. Therefore, instead of using certificate-based authentication algorithms, the proposed mechanism uses the PSK authentication algorithm that uses a pre-shared key to authenticate other parties along with the ECDHE key exchange algorithm. The symbols used to describe different processes in the proposed mechanism are illustrated in Table I.

The ECDHE is used for the key exchange process in the proposed security mechanism. In this process, to use ECC, each party must agree on the domain parameters (p, a, b, G, n, h) that define the elliptic curve. Also, the client and server should have a key pair for elliptic curve cryptography, including a private key d (a random integer) and a public key Q ($Q = dG$). Therefore, the private key d_C and the public key $Q_C = d_C G$ are for client and the keys d_S and $Q_S = d_S G$ are for server. Then, the client and the server exchange their public keys. They calculate the secret key with using their own private key and other party's public key. The client computes $S = d_C Q_S$ and the server computes $S = d_S Q_S$. The shared secret key (S) is equal for both parties since $S = d_C Q_S = d_C d_S G = d_S d_C G = d_S Q_C$ [29].

ECDHE algorithm does not provide authentication on its own, because the key is different every time and any of the parties cannot be confident that the key is from the intended party. Therefore, the Pre Shared Key (PSK) [35] authentication algorithm is used along with ECDHE in order to authenticate both parties.

The PSK authentication algorithm applies a string of characters (64 hexadecimal digits) which is used as an authentication key (shared secret) and shared previously between the client and the server to text encryption. When the secret key is shared between them, they authenticate each other through the four-step procedure Shared Key authentication algorithm [36]. The benefit of the PSK algorithm is to avoid heavy public key calculation to authenticate. The only problem of it is that if the attacker can obtain the shared secret key, previous and future sessions would be compromised. When the proposed mechanism uses PSK along with ECDHE key exchange algorithm, it provides the Perfect Forward Secrecy (PFS) feature that protects past sessions against future compromises by providing a distinct key for each session. Even if the attacker accesses this shared secret somehow, it would only compromise that specific session. Previous or future sessions would not be compromised.

A. Test Environment Architecture

To set up the architecture of the test environment, different suitable hardware was selected.

As can be seen in Fig. 1, there are two Raspberry Pi devices which act as MQTT publisher and subscriber and connected to the router using Wi-Fi connection. The ODROID-C1 acts as the MQTT broker connected through an Ethernet connection to the router. In addition, they connect to the power supply with a power cable. The power measurement hardware device placed between the publisher and the power supply to measure the energy consumption. The parameters that used in the test environment to evaluate the proposed security mechanism are shown in Table II.

Table III illustrates the different layer protocols used in the test environment.

TABLE I. SYMBOLS USED IN THE PROPOSED MECHANISM

symbols	Definition
p	The Prime Case
a, b	Elliptic curve constants
n	The smallest positive number
h	An Integer number called The cofactor
d	Private Key
Q	Public Key
G	Generating Point
S	Secret Key

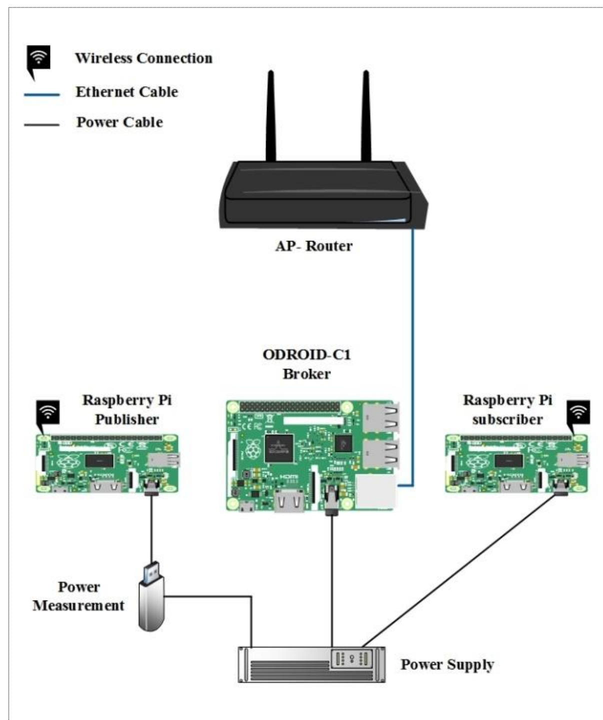

Fig. 1. General Test Environment Architecture.

TABLE II. TEST ENVIRONMENT PARAMETERS

Parameter	value
MQTT Broker	1
MQTT Publisher	1
MQTT Subscriber	1
Number of published messages	30
Message Length	152 byte
Power Measurement Device	1
Access Point-Router	1
Test frequency	60 times

TABLE III. TEST ENVIRONMENT LAYER AND PROTOCOL

Layer	Working Protocol
Radio	IEEE802.11
Link	Ethernet
Network	IPv4/IP6
Transport	TCP
Encryption	TLS
Application	MQTT

B. Test Environment Equipment

The Raspberry Pi Zero W embeds Wi-Fi and Bluetooth v4.1. Its processor is a 1GHz BCM2835 SOC (32-bit ARM-based processor) that operates with 512MB RAM. The ODROID-C1 Single Board Computer (SBC) equipped with an Ethernet interface and two High-Speed USB A-type connectors. It has 1Gbyte DDR3 RAM and 1.5GHz Quad-Core ARMv7 processor. The power measurement device can measure voltages up to 30V and currents up to 5.1A. The AP-Router has Wi-Fi and LAN ports used to connect the Raspberry Pi devices and The ODROID-C1 together.

Besides hardware equipment, some analyzer tools and software used to measure the evaluation metrics. The PERF performance analyzer tool used to monitor CPU clock and execution time. The NMON analyzing tool was used to monitor the CPU utilization percentage. The Wireshark software used to monitor packets transferred between the clients and the broker to calculate bandwidth consumption. The OpenSSL used for Raspberry Pi devices that act as clients and also for the broker, and the C scripts run on the clients. In addition, The Eclipse Paho MQTT installed on the Raspberry Pi devices that act as MQTT clients, and the Eclipse Mosquitto installed on the ODROID-C1 acts as an MQTT broker. Two cipher suites were chosen according to the Internet Engineering Task Force (IETF): TLS-ECDHE-ECDSA-CHACHA20POLY1305-SHA256 and TLS-ECDHE-PSK-CHACHA20POLY1305-SHA256.

The Raspberry Pi device (publisher) starts the tests. A script on it specifies which cipher suite to be used, and then it sends messages to the Broker several times. The resource consumption by each of the MQTT transactions was measured and registered. After all the tests were done, tables and graphs related to the test data were generated.

IV. PERFOMANCE EVALUATION AND DISCUSSION

The proposed security mechanism evaluation was done using a real test environment. In order to evaluate the developed mechanism, three types of scenarios were conducted and the results of them investigated to conclude which security mechanism is more appropriate for the IoT devices. The first scenario is the default security mechanism of MQTT, the second scenario is the ECDHE-ECDSA security mechanism, and the last scenario is the proposed security mechanism which is the ECDHE-PSK. In each scenario, 30 messages with 152-byte length were sent and the test repeated 60 times and the average values were calculated.

The work tested based on four evaluation metrics: including CPU utilization, execution time, bandwidth usage, and power consumption. All these performance metrics tested on three scenarios.

A. Average CPU utilization

Fig. 2 compares the average CPU utilization percentage between three security mechanisms. As can be seen, ECDHE-ECDSA consumed the most CPU percentage, about 60%, since the signing and verification process needs more computation. In comparison, the ECDHE-PSK security mechanisms used 10% less than the ECDHE-ECDSA because it does not use any certificate for authentication. The default security mechanism of MQTT, which used only a simple user name and password for authentication, utilized the lowest CPU.

B. Average Execution Time

According to the bar chart shown in Fig. 3, the highest execution time related to the ECDHE-ECDSA is 2.91 seconds. While the average time fell to 2.58 seconds when the ECDHE-PSK security mechanism executed on the device.

C. Average Bandwidth Consumption

To measure the consumed bandwidth for each security mechanism the following bandwidth equation was used:

$$\text{Consumed Bandwidth (bps)} = \frac{\text{The total size of packets}}{\text{Total Simulation Time}}$$

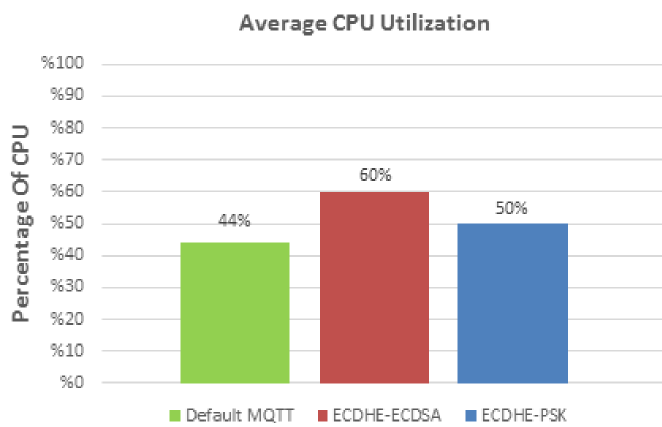

Fig. 2. Average CPU Utilization Percentage of Default MQTT, MQTT with ECDHE-ECDSA and ECDHE-PSK.

Fig. 3. Average Execution Time of Default MQTT, MQTT with ECDHE-ECDSA and ECDHE-PSK.

As shown in Fig. 4, in the default security mechanism of MQTT, the average bandwidth consumption was only 80,391 bps. In the implementation of MQTT with ECDHE-ECDSA security mechanism, the average bandwidth consumption has been increased significantly and reached 154,269 bps because of the certificate which is transferred between publisher and broker in this security mechanism. While the proposed mechanism used only 38,084 bps more than the default security mechanism of the MQTT, its average bandwidth consumption is around 118,475 bps. As can be seen, the authentication mechanism has an effect on increasing bandwidth consumption where extra packets are added to negotiate and they include extra bytes for handling authentication parameters.

D. Average Power Consumption

Power consumption is the other metric. When the traffic volume increases, it will result in higher processing. Therefore, the power consumption increases too. As shown in Fig. 5, the ECDHE-ECDSA security mechanism used by far the highest power due to the signing and verifying certificate.

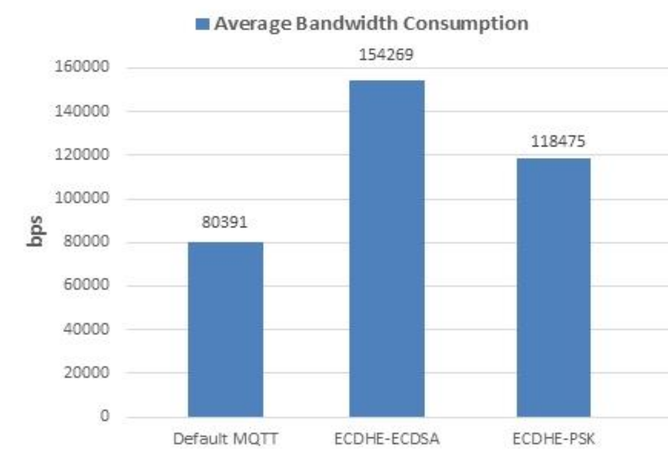

Fig. 4. Average Bandwidth Consumption of Default MQTT, MQTT with ECDHE-ECDSA and ECDHE-PSK.

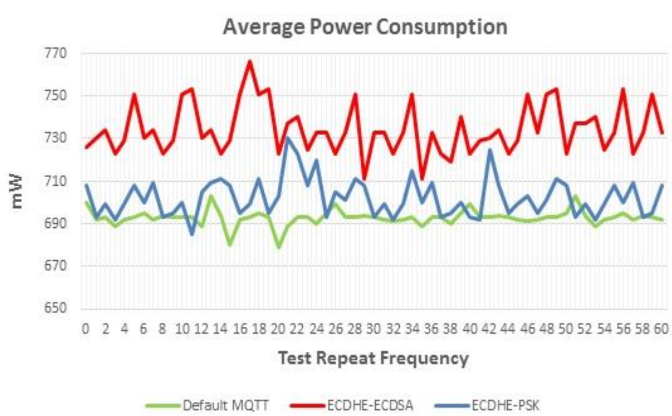

Fig. 5. Average Power Consumption in Default MQTT, MQTT with ECDHE-ECDSA and ECDHE-PSK.

V. CONCLUSION AND FUTURE WORK

The aim of this paper was to propose a lightweight security mechanism for the IoT resource-constrained devices over the MQTT protocol. Since authentication is an unavoidable step to secure communication, the impact of the different authentication algorithms on IoT nodes was evaluated. Most secure authentication algorithms for securing the TLS communications like RSA and ECDSA use a certificate to authenticate other parties that is heavy for IoT devices. The use of a Pre-shared key instead of a certificate can be useful to authenticate IoT devices. Therefore the performance and resource consumption of the ECDHE-PSK authentication algorithm with the ECDHE-ECDSA certificate-based authentication algorithm was evaluated and compared. Since the PSK algorithm does not require a certificate to authenticate; it can decrease the resource consumption of IoT devices significantly. In addition, the ECDHE-PSK provides the Perfect Forward Secrecy (PFS) feature to ensure more secure communication.

After running different evaluations, the proposed security mechanism ECDHE-PSK outperformed ECDHE_ECDSA in all evaluation metrics. It utilized less CPU, execution time, bandwidth, and energy than the ECHDE-ECDSA security mechanism which is one of the most popular and reliable TLS authentication algorithms recently used. It is clear that using a certificate to validate the data will result in more data transfer as well as more CPU usage. The increase in these two factors has an effect on the amount of power consumption too. IoT devices are usually vulnerable because their hardware cannot accommodate the required certificates while reducing power consumption and CPU processing. By using ECDHE-PSK the IoT devices can overcome these limitations.

Since the IoT field is still a new research topic, the existing IoT simulators do not support the latest cipher suites and security mechanisms on the MQTT protocol. Therefore, to evaluate the proposed mechanism, a real testbed was required. It was the first time that this TLS authentication algorithm was implemented and evaluated over the MQTT protocol. Real environment scenarios testing are the only way to determine which security algorithms are more suitable for IoT devices.

An interesting issue for future work is implementing this security mechanism on a bigger scale with more IoT devices and sensors to evaluate different metrics where the network is under high traffic load. Besides this, some attack scenarios can be simulated to evaluate attack resistance of the security mechanism against common attacks.

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Factors Affecting SME Owners in Adopting ICT in Business using Thematic Analysis

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***Abstract*—In Malaysia, Small Medium Enterprise (SME) has become the main contributor for the income generation and employment thus are expected to increase country's GDP growth. Hence, it is important for the SME owners to ensure the sustainability of their business in today's business settings that has moved to digital businesses in which technology is used to create new value in business models, customer experiences and the internal capabilities that support its core operations. Yet, there are still local SMEs who did not fully utilized the advantages of adopting Information and Communications Technology (ICT) in their business operation and transactions. This paper presents an interview done with 12 SME owners that operates their businesses in Kuala Lumpur and Selangor. The study is to gain an understanding on the factors affecting SME owners in adopting ICT in their business by using the Thematic Analysis method. The outcome shows that there are two central themes that affect ICT usage in SME which are the (1) Internal Factor and (2) External Factor. Further, we identified two (2) components that effect the Internal Factor, namely Company (capital, company's age, less skilled workers and family business) and SME Owners (time, education, perceptions and experiences) and another two (2) components that affect the External Factor, namely Technology (high cost, complicated, system's security and stability) and Regulators (government's initiatives, training skills and no urgency). Hence, the result is important to the SME owners and management as well as the government or the authorities to resolve these issues in order to increase the ICT usage among the SME owners in Malaysia.**

Keywords*—*Small Medium Enterprise (SME); Information and Communications Technology (ICT); thematic analysis; internal factors; external factor

I. Introduction

With the advancement of computer technology, businesses are urged to adopt ICT in order to keep abreast of technology development and maintain its sustainability. The ICT is widely used in all sectors including business, especially in Malaysia. In today's business operation and transactions, ICT are made reliable to every person. Thus, SME owners are encouraged to choose for this option as argued by [40], there are still SMEs in the rural areas who did not fully utilized ICT usage in their business. The disadvantages to the business are that it will be less competitive [31], less productivity [4] and lagged behind [23]. The technology revolution has forced everyone to stay ahead of the technology to experience the advantages [44] of using it.

It is not an easy task to ensure SMEs in Malaysia to fully adopt ICT for their businesses. There are several factors that contribute to the low adoption of the ICT in SME. Issues such as lack of ICT knowledge [42] and limited budget for an ICT investment [5] have been identified as the main barrier for SME owners to adopt ICT. Moreover, individual capabilities have a huge effect on the adoption as well. The unpleasant past experiences in handling ICT [47] can also change SME owner's perception to fully adopt ICT. Thus, the existing issues need to be highlighted first by the SME owners and the government in order to increase the ICT adoption amongst SMEs in Malaysia. The objective of this study is to identify factors that affect SME owners to adopt ICT for their businesses. This study uses thematic analysis method through interview sessions with twelve (12) SME owners in Kuala Lumpur and Selangor, Malaysia.

The rest of the paper is organized as follows. Section 2 discusses the background of several topics that are related to ICT, SME, Thematic Analysis, Impact on ICT Diffusion and Factors Affecting SME owners to adopt ICT. Then Section 3 provides a description of the methodology of the proposed framework for Thematic Analysis. This is followed by Section 4 with a demonstration of the experimental results and findings. Finally, in Sections 5 and 6, the paper is concluded with a brief discussion and the future research work.

II. Background and Related Work

A. Information and Communication Technology in Business

ICT is the terminology for processing and communicating information. ICT is divided into two, namely information technology and communication technology. The scope of ICT covers everything related to storage, retrieve, manipulate, transmit or receive information electronically in digital form such as personal computers, digital televisions, emails and robots. The ICT is expanding globally and the development is expected to contribute in all areas especially in business. The reason is because, ICT is one of the sources of economic growth of the country. Furthermore, it is found that the use of ICT in business in improving access to customers and other business partners as well as to improve business performance to achieve to the optimum level [35]. Businesses use computers and software to run their operations more smoothly. They utilize ICT in various departments namely finance, manufacturing, human resources, and security [26].

B. Small Medium Enterprise in Malaysia

According to [9], 907,065 organizations (98.5%) registered in Malaysia are SMEs. The sectors in the SMEs were Services (89.2%), Manufacturing (5.3%), Construction (4.3%), Agriculture (1.1%) and Mining & Quarrying (0.1%). For the Manufacturing sector, it is considered as SMEs if the companies' annual sales do not exceed RM50 million or full-time employees do not exceed 200 people. For the Services and other sectors, their annual sales do not exceed RM20 million or full-time employees do not exceed 75 people. SME is defined based on company's annual sales or full-time employees. The advantages of having many SMEs in the country are to ensure the country's economic growth [30] and offer employability [16] to the nation. A research by [37] discovered that the initiative of the public university in promoting entrepreneurial activities is a good move. This is to inculcate the interest and business mind set to the students in order to inspire them to set up a business as to reduce the number of unemployment in Malaysia.

C. Factors Affecting ICT usage among SME Owners

ICT plays an important role in improving business performance and profitability. However, the SME owner's attitude and knowledge in ICT are the key determinants of a business in accepting ICT [40]. Other factors that contribute to the low usage of ICT in SMEs are due to internal and external factors [20]. Internal factors include experience in ICT and organizational size. According to [8], the external factors that influence the use of ICT among SMEs are the industry structure, presence of technology service providers and regulation. In addition, [19] have listed other factors that also contribute to the adoption and use of ICT in business, which is an appropriate business plan, implementation strategy and requires in-depth knowledge of ICT.

There are also other studies that conclude that SME owners' expertise and involvement in ICT, supply chain features and government policy are important factors in shaping ICT acceptance among SMEs [20]. There are still doubts and challenges associated with privacy and security of ICT systems. There is a risk that the data made from all connected machines and devices, can ended up being misused [1]. On the other hand, [43] added that the factors affecting the ICT usage among the SME owners are the effort expectancy, social influence and facilitating conditions. Not only that, [32] claimed that, the main hindrance to the use of ICT is the complexity of their organizational structure in situations where the complexity of the environment impacted the use of ICT for effective integration and use of market information. Therefore, all these factors should be addressed well by the SME owners in order to ensure that they use ICT for their business' sustainable growth [49].

D. Impact of ICT Diffusion in SME

The use of ICT has become a necessity in today's business activities but there is still limited usage of ICT among businesses in Malaysia especially in rural areas [41]. This is a worrying situation as SMEs who do not adopt ICT will face difficulties in making the company visible to larger markets and to ensure sustainability. The study by [33] found that lack of access to ICT hindered Malaysia's SME to business' innovation growth. A research by [17] argue that SMEs, led by owners who are lack in basic knowledge in ICT, will lose their potential in their business. ICT contributes significantly to today's business transactions. Thus, SMEs are encouraged to adapt their purchases online so that with these trading platforms, they will enable all types of customer orders [36] and, in turn, increase the company's revenue and profitability. SMEs are also encouraged to continue to use ICT as it can generate effective business plans, access databases, and improve communication and social networks [50]. She added, the global environment is exposed to current challenges that should not be overlooked. The use of ICT has provided many opportunities for SMEs to avoid this challenge and maintain a sustainable competitive advantage by utilizing existing resources.

E. Thematic Analysis

Each qualitative research approach has specific techniques for controlling, documenting, and evaluating data analysis processes. The researcher is responsible to ensure the accuracy and relevancy of the said technique. Research by [10] had developed Thematic Analysis which was later applied in various fields of study. According to them, Thematic Analysis is the process of identifying patterns or themes in qualitative data. The goal of Thematic Analysis is to identify themes from the important data, and use this theme to address an issue in research. Thematic Analysis method not only summarizes the data, but also interprets and understands it better. Interview methods have been identified as the main method for finding themes. They have also listed six phases in doing the thematic analysis. Table I shows the phases and the descriptions of Thematic Analysis.

1) Phase 1: Familiarizing Yourself with the Data: The first step in qualitative analysis by [10] is to read and understand the transcript. The researcher should understand all the data that may be useful to make notes and make an initial impression.

TABLE I. THEMATIC ANALYSIS PHASES BY [10]

Phase	Description
1	Familiarizing yourself with the data
2	Generating initial codes
3	Searching for themes
4	Reviewing potential themes
5	Defining themes
6	Producing the report

2) Phase 2: Generating Initial Codes: In this phase, [10] highlight that researcher needs to manage the data in a meaningful and systematic way to reduce the amount of data into a more focused meaning. Researcher needs to encode each segment of the relevant data on the research question and use the open code when it does not have a pre-set code but develop and modify the code through the coding process. After taking the first step, researcher needs to discuss and develop some introductory ideas about the code. Then, setting up the transcript code is done separately. Encoding is performed on each segment of the relevant text to address the research question. The code is then compared and discussed before moving to another transcript. Researcher has the options to manually use either a printed transcript and a pen or to use qualitative data analytics software such as ATLAS.ti and Nvivo which is useful when dealing with large data sets. According to [11], Microsoft Excel can also be used to code and identify themes.

3) Phase 3: Searching for Teams: As previously defined by [10], themes are patterns that capture something important about data from research questions. If there is a very small data set, there might be similar data between the encoding level and the initial theme identification level. In this case we are looking at codes that eventually become the theme. At the end of this step, the code has been organized into a broader theme that seems to say something specific about this research question. This theme is mostly descriptive, which is to illustrate the patterns in the data related to the research questions. Most codes are associated with one theme, though some are linked to more than one.

4) Phase 4: Reviewing Potential Themes: The study by [10] defines this phase for study, refine and develop the preliminary themes identified in Phase 3. At this point, it is useful to collect all the data related to each theme and classify them by colors and consider the importance. The next step is to figure out how the theme works in one single interview and across all interviews. The themes should be clear and they should be different from each other.

5) Phase 5: Defining Themes: This is the final refinement of the theme which [10] set the goal to identify the essence of the theme; themes that you want to talk about, if there are sub-themes, how they interact and relate to the main themes and each other. In this analysis, feedback is a comprehensive theme rooted in other themes.

6) Phase 6: Producing the Reports: Finally, the results of this thematic analysis will be written in the form of a report.

F. Advantages of Thematic Analysis

Thematic Analysis is a qualitative method that can be easily learnt because it includes complete methods and procedures [10]. Author in [24] argues that this method can summarize key features in large data sets because the researcher needs to be more structured in handling data and producing a good report. This clearly demonstrates that the method provides unique flexibility according to the research questions and data forms developed by the researcher. This Thematic Analysis can be used to answer questions about their experiences, perspectives, practices, and behaviors. The qualitative data generated is through respondents in direct interaction or writing feedback to questions including secondary data sources. Next, it can be used for small and large data sets. Qualitative research should show that the analysis performed is reliable, accurate, consistent, and covers the whole through the recording, being systematic with complete details to prove that such a method of Thematic Analysis is reliable to use [34]. For the number of participants, [28] suggests that four is the minimum participant's number who came from different backgrounds to get clear picture on the issues faced.

III. Methodology of Framework

In this paper, the study was conducted using qualitative method. Interviews had been done with twelve (12) SME owners and analysed using Thematic Analysis model developed by [10]. It is a method of identifying and analysing patterns in data sets and illustrating which themes are most important. The Thematic Analysis Model is suitable for this study as the process begins when the researcher identified potential issues during data collection [10]. Research by [3] had use different tool to analyze the data which is the Structural Equation Modelling (SEM). The quantitative statistical analysis is quite complex in terms of the procedure compared to Thematic Analysis.

A. Materials

The method used for this study was through interview sessions. Interviews were used to gather information on the reasons why SME owners in Malaysia are less involved in the use of ICT and technology in conducting their business activities. The first part of the interview form was initiated with informed consent requesting that each respondent agree to be recorded using a Sony ICD-UX543F digital voice recorder.

Next, demographic questions are provided in the second part of the interview form to gather more information about respondents and their businesses. The third part of the form is the questions used by the researcher in the interview session. The questions were used as the basis of the interview and the researcher had the right to add other questions depending on the answers provided by the respondents. This is to capture the real comments, reactions and realities faced by the respondents in sharing information about the usage of ICT and the day-to-day business situations and experience. After recording the data from the respondents, the researcher transcribed the data into digital text and used Microsoft Excel to store the data. Survey data were then analysed using Thematic Analysis method. The list of interview questions are as follows:

Business Background

1. How did you come up with the idea of starting the business?
2. What are the factors that drive you to set up the business?
3. How are you looking at competition today?
4. What actions / efforts did you take to overcome competition?
5. What do you do to increase knowledge / skills of the current business?

6. What are the challenges that you have to face in the business?
7. Do you have a mentor in business and how does it affect the business?

Factors affecting SME owners to adopt ICT

1. Do you use ICT and technology in your business?
2. List the technologies used in this business.
3. What is your opinion on the usage of ICT?
4. Are you aware of the benefits of ICT and technology?
5. Have you ever attended courses that involve the usage of ICT?
6. How did they invite you to attend this course?
7. Do you think the course helped you to increase the usage of ICT?
8. Do you agree with the content provided by the course?
9. Before attending a course, did you know what will be taught?
10. What is the duration of the course?
11. Give your personal opinion on the courses you have attended.
12. What are the barriers in you in adopting ICT in your business?

B. Participants

A total of 12 SME owners agreed to participate in this study. All respondents were randomly selected after identifying their personal and business backgrounds. The male respondents were 3 (25%) and the women were 9 (75%) as shown in Fig. 1. The diagram below shows infographics distributions by their respective groups.

Fig. 2 illustrates the respondents' ages ranged from 32 to 63 (Mean: 45.25; Standard Deviation: 11.371).

Fig. 3 demonstrates the higher education levels for all respondents. They range from SPM (25%), Certificate (8.33%), Diploma (41.67%) and Bachelor's Degree (25%).

Fig. 4 shows the respondent's type of business which shows 33.33% based on products and 66.67% by services.

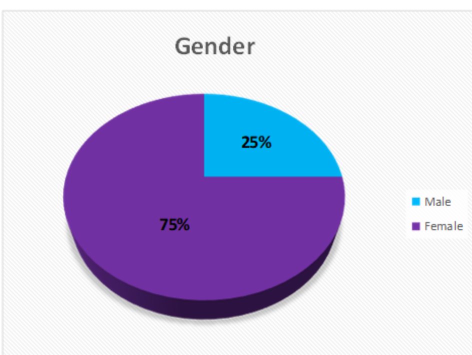

Fig. 1. Distribution of Respondents by Gender.

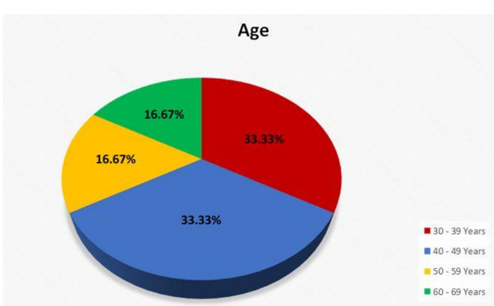

Fig. 2. Distribution of Respondent's Age.

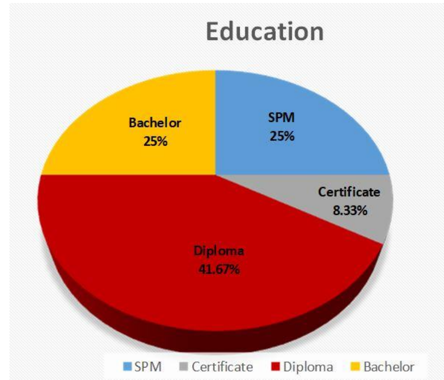

Fig. 3. Distribution of Respondent's Education.

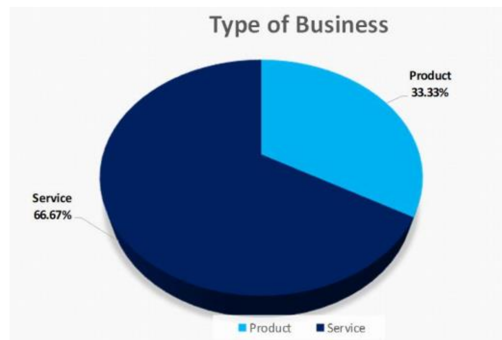

Fig. 4. Distribution of Respondent's Type of Business.

All respondents have been in business for 3 to 43 years. Fig. 5 illustrates the percentages of the years of services. 50% of the respondents had been in business from 1 to 15 years, 33.34% from 16 to 30 years and 16.66% from 31 to 45 years.

Table II shows the background details of all respondents. The details are the respondent's age, education, years of business establishments, type of business and the business they are running. The twelve (12) respondents came from various business backgrounds. Their age ranges from 32 to 63 years old. The year of establishments started from 1977 to 2015. The type of business that they run fall under the category of product (33.33%) and services (66.67%). Details are as follows:

Fig. 5. FDistribution of Respondent's Years of Services.

TABLE II. BACKGROUND DETAILS OF THE 12 RESPONDENTS

Respondents	Age	Education	Year of Establish-ment	Type of Business	Business
I1	47	Certificate	2013	Service	Tailor
I2	32	Bachelor	2015	Product	Baby and Kids Products
I3	63	Bachelor	2001	Product	Used Cars
I4	37	Diploma	2017	Service	Barber
I5	32	Diploma	2010	Service	Beauty Salon
I6	32	Diploma	1989	Product	Bread and Pastries
I7	61	Diploma	1977	Product	Retails
I8	56	SPM	1992	Service	Catering
I9	49	SPM	2011	Service	Asam Pedas Restaurant
I10	54	Diploma	1998	Service	Tomyam Restaurant
I11	40	Bachelor	1996	Service	Law Firm
I12	40	SPM	1997	Service	Rental Houses

C. Procedure

This study was conducted using the interview method. The requirement for the respondents is SME owners who have been in business for more than 3 years by selling products or offering services. The selection of respondents was done randomly and business was conducted around Kuala Lumpur and Selangor, Malaysia. The researcher contacted the respondents and set an appointment. After setting up the place and time, both researcher and respondent met. The researcher described the study to be followed and the respondents were then asked to sign the consent form to allow the interview to be recorded and to fill out personal and business information on both forms. During the interview, the researcher used questions in the third section of the form and occasionally added questions depending on the answers and the responses provided by the respondents. As a token of appreciation, the researcher presented an Aeon voucher worth RM20 at the end of the interview. The same process was repeated until the 12th respondent.

1) Phase 1: Familiarizing Yourself with the Data: Upon completion of the interview, the researcher collects all audio data and upload the file to a laptop and created a set of storage files for security purposes. All twelve (12) audio data were then transcribed into words using Microsoft Excel software. The Excel data was then printed, and repeated readings were used to understand the details of the interviews.

2) Phase 2: Generating Initial Codes: Based on the set of questions being asked during the interview session, the researcher attempted to obtain a starting code based on the answers provided by the respondents. The researcher then reduced these data to more focused and important data. After generating nearly nine types of codes and classifying them using different pencil colors, they were then passed on to the second and subsequent transcript.

3) Phase 3: Searching for Themes: After identifying the starting code, the third phase was conducted to find themes by assembling codes and formed the same set of data sets for each transcript.

4) Phase 4: Reviewing Potential Themes: After finding the theme, the researcher modified and developed the initial theme and revised it to meet the objectives of this study. Data was then reviewed repeatedly and stored only for the sake of importance. The theme should be clear with the objectives of the study and should be found in all twelve (12) transcripts.

5) Phase 5: Defining Themes: The researcher then analysed and determined the themes and then searched for sub-themes where the data interacted with the main themes in the data set.

6) Phase 6: Producing the Report: After obtaining codes, themes, sub-themes and sub sub-themes, the researcher then formulated a model framework based on the findings from the study. A report was produced that includes the study objectives, literature review, methodology, analysis, results and comprehensive discussion on this thematic analysis study.

IV. EXPERIMENTAL RESULTS AND FINDINGS

The thematic analysis produces several factors that contribute to SME owners on ICT acceptance. Fig. 6 illustrates the analysis of the Factors Affecting SME Owners in Adopting ICT in their business. The analysis is divided into two (2) central themes which are Internal and External Factors. For Internal Factors, the researcher identified two (2) sub-themes which are Company and SME Owners. For Company, the factors are due to lack of capital, depending on company's age, less skilled workers and mostly because they run their family business. For SME Owner factors, the lists are lack of time, education background, owner's perception and owner's bad experiences with ICT usage. Internal factors relate to everything that beyond the company's control. For External Factors, they are divided into two (2) sub-themes which are Technology and Regulators. Under Technology, the factors that contributed to the lack of ICT adoption are because of the system's high cost, complicated systems and the doubt on the system's security and stability. For Regulators, the factors are to the government's initiatives, issues in the skills enhancement courses and there is no urgency to adopt ICT in certain industries.

Fig. 6. Factors Affecting SME Owners in Adopting ICT in their Business.

Table III is the analysis using the Thematic Analysis method to identified the themes. It is setup with the codes derived by the researcher according to same set of answers given by the respondents. Researcher identified two (2) respondents were saying about the factors that makes they didn't opt to use ICT which was the age of the company. They started the business early and they claimed that the company and their age had affected the decision to use the ICT. Below is the selected narrative:

"We're actually very old and traditional. I didn't use to learn ICT" – Respondent 8

For the code of lack of capital, seven (7) respondents were quoting the similar reasons. The main constraints are the limited cost and capital that makes them choose not to use ICT in their business. Below are the selected narratives:

"It's fast, it's easy but it's a budget issue, which means financial constraints" – Respondent 1

"One of them is the cost" – Respondent 2

"Ok, I think it's financial" – Respondent 5

Four (4) of the respondents agree that the next factors are the lack of ICT Skilled Workers as per below narratives:

"Challenge here is to train our staff" - Respondent 2

"We want to go that way but because of the staff constraints, nobody can operate it" - Respondent 7

"But the limitation is our 'smart' workers. So it doesn't work as efficient as I wish" - Respondent 10

"We have to have people who are experts in accounting" - Respondent 12

While another four (4) respondents stating that they run their family business and prefer the traditional way of handling business. The narrative is as below:

"This is a family business so my father-in-law likes the traditional way" – Respondent 12

For the sub-theme of Owner, the derivation started from the coding of lack of time because of the busy work schedule. Three (3) respondents agreed that time is their main constraints that hinder them to use an ICT in their business operations as per the following narratives:

"if there is any (training), I can but I need to look at my schedule" – Respondent 6

"We want to standardize our menu but the time limits us" – Respondent 10

"Time constraints for me to do that" – Respondent 12

Four (4) respondents quoted that their knowledge to ICT is limited and relate to their education backgrounds. The narratives are as follows:

"Limited knowledge" - Respondent 1

"One without knowledge" - Respondent 3

"because there is limited knowledge, there is no one to teach" - Respondent 5

"In fact Kak Lin is not very expert. So, I need to get my children to help me to use ICT" – Respondent 9

For the sub sub-theme for perception, three (3) respondents shared their bad perceptions towards using ICT in their business. They had negative thoughts generally on being scammed as per below narratives:

"People can cheat us; we don't know them" – Respondent 1.

"We are afraid to use all this ICT thing if scammers still exist" – Respondent 3

"I've heard so many negative things from my customers" – Respondent 9

It was then related to the next code which is real experiences and three (3) of the respondents revealed that they had been cheated and had suffered from loss. The narratives are as below:

TABLE III. ANALYSIS FOR FACTORS INFLUENCING SME OWNERS IN ADOPTING ICT IN BUSINESS

THEME	SUB-THEME	SUB SUB-THEME	CODE	NARRATIVE	RESPON-DENT
Internal	Company	Company's Age	Traditional and old companies	"In 2001, the business that I thought was selling cars" - R3 "We're actually very old and traditional. I didn't use to learn ICT" - R8	R3, R8
		Capital	Lack of capital	"It's fast, it's easy but it's a budget issue, which means financial constraints" - R1 "One of them is the cost" - R2 "Ok, I think it's financial" - R5 "I want the system cheap but also has to be functional" - R7 "The challenge when we do business is the capital is at our own cost and never borrow at all. So,we start with small amount"- R9 "I'm thinking back to financial constraints" - R10 "Cost is one thing; we have to buy software" - R12	R1, R2, R5, R7, R9, R10, R12
		Less Skilled Workers	Lack of ICT skilled workers	"The challenge here is to train our staff" - R2 "We want to go that way but because of the staff constraints, nobody can operate it" - R7 "But the limitation is our 'smart' workers. So it doesn't work as efficient as I wish"- R10 "We have to have people who are experts in accounting" - R12	R2, R7, R10, R12
		Family Business	Family Business History	"My dad used to make bread from Muar. He quit his military service and started making bread out of curiosity" - R6 "The store is part of family business, so after he retired, we operated from 1977 till now" - R7 "Back then, my mother-in-law ran a small house-to-house cooking for small wedding" - R8 "This is family business so my father-in-law like the traditional way" - R12	R6, R7, R8, R12
Internal	Owner	Time	Lack of time because of the busy work	"if there is any (training), I can but I need to look at my schedule" - R6 "We want to standardize our menu but the time limits us" - R10 "Time constraints for me to do that" - R12	R6, R10, R12
		Education	SME owners' knowledge of ICT is limited	"Limited knowledge" - R1 "One without knowledge" - R3 "because there is limited knowledge, there is no one to teach" - R5 "In fact Kak Lin is not very expert. So, I need to get my children to help me to use ICT" - R9	R1, R3, R5, R9
		Perception	There are many negative responses to ICT usage	"People can cheat us; we don't know them" - R1 "We are afraid to use all this ICT thing if scammers still exist" - R3 "I've heard so many negative things from my customers" - R9	R1, R3, R9
		Experience	Previous experience has made SMEs choose not to use ICT	"Many scammers, they called me and said they are lawyers and I didn't pay for my debts and many more cases" - R3 "I've been scammed through FB; the loss was RM700" - R5 "I've been cheated; not once but twice" - R9	R3, R5, R9
External	Technology	High Cost	The installation of infrastructure and ICT equipment is costly	"The biggest downside is the cost of the ICT products"-R4 "I think the cost is a bit high for me" - R5 "See how much it costs, I can't afford if I have to pay a lot" - R7 "The ICT is a good help but is quite expensive" - R10	R4, R5, R7, R10
		Complicated	Complex interface	"ICT systems are difficult. It's not easy to remember interfaces in the system" - R1 "I don't want it to be complex because the one that we had were so complicated to me " - R7 "The system is complicated for us because it always has to be updated or renew (license)" - R9	R1, R7, R9

External	Technology	System's Security / Stability	Doubts on the security and stability of the ICT system	"for example in the security of the ICT system, sometimes we don't know it" - R1 "Sometimes disadvantage is the ICT's security. Not sure about security" - R3 "I doubt the stability of this ICT system" - R4 "I am afraid he will say:" You have to be more careful, as you might lose your money easily" - R9	R1, R3, R4, R9
	Regulators	Government Initiative	Opinions on government initiatives in promoting the use of ICT	"Kasih Ibu Smart Selangor (KISS). Anyone who has that privilege card can come here and can buy anything" - R7 " I want them badly (training). Those things are necessary right now. If you don't know the updates, then you will be left behind" - R9 "To me, if you want to teach people, you don't look down on them. Even if he sells banana fritters, you have to teach them how to run their business well. Maybe they can pack nicely" - R10 "In my opinion, it is good and we welcome the government's initiative to create more effective lawyers especially in dealing with ICT" - R11	R7, R9, R10, R11
		Skills Enhancement Course	Feedback on courses taken	"It is compulsory for us to attend 21 days of very challenging mental and physical courses in order for us to get the funds" - R1 "Sometimes this course requires payment" - R1 "I thought that anything related to learning ICT needs payment" - R9 "but the input they gave us is nothing. To me, they didn't teach us anything" - R10	R1, R9, R10
		No Urgency	No requirements and authorities do not encourage to use ICT	"because the need is not urgent" - R11 "there is no need/urgency and demand for such things (ICT)" - R12	R11, R12

"Many scammers, they called me and said they are lawyers and I didn't pay for my debts and many more cases" – Respondent 3

"I've been scammed through FB; the loss was RM700" – Respondent 5

"I've been cheated; not once but twice" – Respondent 9

For the External Factor which is Technology, the derivation was started off with the finding of coding stated that the installation of infrastructure and ICT equipment is costly. Four (4) respondents gave the same feedback which is the ICT are expensive and they cannot afford the cost.

"The biggest downside is the cost of the ICT products"- Respondent 4

"I think the cost is a bit high for me" – Respondent 5

"See how much it costs, I can't afford if I have to pay a lot" – Respondent 7

"The ICT is a good help but is quite expensive" – Respondent 10

Next coding is the complex interface that makes the ICT system complicated. Three (3) respondents quoted that they had been facing the complex system and they find it difficult. The narratives are as below:

"ICT systems are difficult. It's not easy to remember interfaces in the system" – Respondent 1

"I don't want it to be complex because the one that we had was so complicated to me " - Respondent 7

"The system is complicated for us because it always has to be updated or renewed (license)" - Respondent 9

Four (4) respondents had doubts on the security and stability of the ICT system that falls under the Technology sub-theme. The narratives are as follows:

"for example in the security of the ICT system, sometimes we don't know it" – Respondent 1

"Sometimes disadvantage is the ICT's security. Not sure about security" - Respondent 3

"I doubt the stability of this ICT system" - Respondent 4

"I am afraid he will say:" You have to be more careful, as you might lose your money easily" - Respondent 9

For the sub-theme of Regulators, four (4) respondents had given good opinions to the code of government's initiatives in promoting the usage of ICT. The narratives are as below:

"Kasih Ibu Smart Selangor (KISS). Anyone who has that privilege card can come here and can buy anything" - Respondent 7

" I want them badly (training). Those things are necessary right now. If you don't know the updates, then you will be left behind" - Respondent 9

"To me, if you want to teach people, you don't look down on them. Even if he sells banana fritters, you have to teach them how to run their business well. Maybe they can pack nicely" - Respondent 10

"In my opinion, it is good and we welcome the government's initiative to create more effective lawyers especially in dealing with ICT" - Respondent 11

Unfortunately, for the code of feedback on the courses taken, three (3) respondents argued that, the content and the procedure of the courses they attended. The narratives are as below:

“It is compulsory for us to attend 21 days of very challenging mental and physical courses in order for us to get the funds" - Respondent 1

"Sometimes this course requires payment" - Respondent 1

"I thought that anything related to learning ICT needs payment" - Respondent 9

"but the input they gave us is nothing. To me, they didn't teach us anything" - Respondent 10

For the sub sub-theme of No Urgency under regulators, the code was no requirements and authorities do not encourage the usage of ICT. The researcher notes that, there are still industries that does not need the players (business) to use ICT to their operations and that make sense on why certain businesses did not opt to use ICT. The narratives are as below:

"because the need is not urgent" – Respondent 11

"there is no need/urgency and demand for such things (ICT)" – Respondent 12

V. Discussion

Based on the interviews with twelve (12) SME owners, there are two (2) central themes that influence the use of ICT in business in Malaysia. Using Thematic Analysis method, the central themes are Internal and External factors. Table IV illustrate Internal factors include two sub-themes which are company and owner. These two sub-themes are divided into four sub sub-themes. The sub sub-themes for the company are the company’s age, capital, less ICT skilled workers and family business while the sub sub-themes for the owner are the time, education, perception and experience.

For external factor, Table V illustrate the sub-themes are technology and regulators, which are divided into three sub sub-themes for each theme. For Technology, the sub-themes are high cost, complicated and system’s security and stability. Meanwhile, the sub-themes for regulators are government initiatives, skilled enhancement courses and no urgency. These sub-themes and sub sub-themes were found after starting with the search for the code as the initial keyword.

The interview questions were varies and it is up to the researcher to ask more questions after the respondents had given their opinions. As a result from this Thematic Analysis method, the agenda and objectives in the same code are provided by all the owners of the SMEs who then formulated the themes, sub-themes and sub sub-themes in analyzing the results of this interview. The same foundation suggests that ICT usage factors would be better if they were being analyzed thoroughly, thus could increase the usage of ICT among the SME owners. The theme of internal factors of the company are the age of the company [20], [15], limited capital [39], [12], [7], less skilled workers [17] and family business [6], [18]. The derivation of these sub-themes indicated that the management should overcome all the problems arise hence will help to increase the ICT usage in their business. Author in [45] suggests that SME owners could find ways to manage the competitive and fast-paced technology by investing in ICT specifically to ensure that social networks such as strategic partners and customers are well maintained. In addition, SME owners must be proactive in preparing the entire organization so that all information and knowledge is readily available and essential for management to create a platform for employees to welcome change and support innovation [20]. To inculcate the business management skills among the generation nowadays, [22] suggested that the entrepreneurship education should be taught as early as in their high school.

Another themes of the owner's internal factors are time [39], education [14], perception [2] and experience. Most SME owners do not develop themselves and their companies with the advanced knowledge and thus their knowledge is rather limited especially in the field of ICT. This is agreed by [18] who said that the education contributes to the long-term effect in economic sector. Likewise, for the time factor, SME owners should spend more time discovering new ways of managing and developing new technologies that can elevate their business to a better position. SME owners have a significant impact on financial decisions [25] and business, therefore, they have to move forward and leave behind bad experiences [15] such as capital loss and negative perceptions related to the use of ICT as it will only making their business less competitive.

Then, the technology factors [29] are high cost [48], complicated system [21] and system’s security and stability [46]. For SME owners, they want a user-friendly system and make it easier for them to manage their day-to-day business activities. Therefore, it is important for software developers to simplify their system’s development and at reasonable cost because according to [38], IT solutions should be user-friendly and intuitive to learn. Security [21] and system stability are also factors that make SME owners less likely to use ICT because they fear that if they make mistakes, they will lose their money.

TABLE IV. INTERNAL FACTORS

THEME	SUB-THEME	SUB SUB-THEME
Internal	Company	Company’s Age
		Capital
		Less Skilled Workers
		Family Business
	Owner	Time
		Education
		Perception
		Experience

TABLE V. EXTERNAL FACTORS

THEME	SUB-THEME	SUB SUB-THEME
External	Technology	High Cost
		Complicated
		System’s Security and Stability
	Regulators	Government Initiatives
		Skilled Enhancement Courses
		No Urgency

The themes of external factors of regulators are government initiatives [36] skills improvement courses [13], [27] and no urgency. The respondents welcomed any government initiative in promoting the use of ICT [14] among SME owners and thus increased their income in business. However, there were also feedback from respondents who wanted them to have useful inputs and knowledge that could be used for their business rather than being forced to attend the training in order to be selected to apply for grants or loan. Some even think they have to pay for the courses attended. Authorities are encouraged to provide a clear and comprehensive explanation to ensure all SME owners have the same information and can consider participating in the course if they can arrange their time and staff. In an effort to encourage SME owners to use ICT in their businesses, there are still sectors and areas of business that put no urgency in adopting ICT. Therefore, regulators should view ICT as an initiative that can save time and cost. From there, it can only be realized that the impact of the role of ICT is very important and impacting business.

VI. Conclusion

This study was established to analyze the factors affecting Malaysian SME owners in adopting ICT in their businesses. Interview sessions were done with twelve (12) SME owners who run businesses around Kuala Lumpur and Selangor, Malaysia. Using the Thematic Analysis method, the researcher found that there were internal and external factors that led to less usage of ICT in SME's business activities. The derivation of the factors retrieved from the initial code that had been generated through all twelve (12) transcripts. The initial codes then led to the discoveries of sub-themes and themes. For internal factors, company and owners are the two main factors that affect the less usage of ICT in business. It is followed by the other two factors which are technology and regulators which falls under external factors. From these findings, owners and the management of a company may find it useful to ensure efforts and actions are taken into consideration to make the adoption of ICT in their business operation a success. This is due to the spike in the usage of ICT especially by the customers during this advanced technology time. Businesses are urged to take necessary actions to ensure the adoption of ICT is at a higher rate as well as to maintain the sustainability of their business. The suggestion for future research is to include more participants with different SME owner's age and businesses in rural areas.

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Emotional Impact for Predicting Student Performance in Intelligent Tutoring Systems (ITS)

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***Abstract*—Current Intelligent Tutoring Systems (ITS) provide better recommendations for students to improve their learning. These recommendations mainly involve students' performance prediction, which remains problematic for ITS, despite the significant improvements made by prediction methods such as Matrix Factorization (MF). The present contribution therefore aims to provide a solution to this prediction problem by proposing an approach that combines Multiple Linear Regression (Modelling Emotional Impact) and a Weighted Multi-Relational Matrix Factorization model to take advantage of both student cognitive and emotional faculties. This approach takes into account not only the relationships that exist between students, tasks and skills, but also students' emotions. Experimental results on a set of pedagogical data collected from 250 students show that our approach significantly improves the results of Student Performance Prediction.**

Keywords*—*Intelligent tutoring system; student performance prediction; matrix factorization; emotional impact; achievement emotions

I. Introduction

Computer learning systems, in particular Intelligent Tutoring Systems occupy a preponderant place today. These systems are IT environments that aim to best imitate the behavior of a human tutor in his capacity as a field expert and educational expert. Current researches are based on some domains such as student modelling in general and student performance prediction in particular. Let's mention that the student performance prediction in learning systems remains a major research issue because it predicts its performance for different skills over time [1]. In addition, it makes it possible to determine the next content to be presented to the student to give continuity to his learning [2]. Indeed, in the absence of a good prediction, presenting students with activities that are too easy for example can limit learning on the one hand, and on the other hand, presenting difficult activities can also lead to a misunderstanding and demotivation that are too strenuous also risk leading to poor understanding and loss of motivation [3].

Therefore, for student adequate learning, it is important that current systems have relevant information or attributes (characteristics) to refine the results of performance prediction. Besides, for a better understanding of the educational paths of students, it is useful not to limit information taking only to cognitive or economic areas, but to also have information on the emotional state of students. The emotion, not being always taken into account in the systems of prediction, it generally leads to less efficient systems. Indeed, for specialists in Educational Psychology and neuroscience such as Immordino-Yang [4], emotions are almost essential at the neurobiological level to create memories, engage complex thoughts or even come to significant decisions. They are important for our physical survival as well as our social or intellectual life [4]. Giving systems the ability to integrate emotional aspect will allow them to better understand the student's needs and to react accordingly. This is, moreover, the objective of the research area in affective computing [5] [6]. Our objective is therefore to provide our model with significant data such as emotion to increase the quality of performance prediction.

This paper is organized according to the following order: Section 2 provides a State-of-The-Art of techniques and attributes used to predict student performance. Section 3 in turn presents classic Matrix Factorization techniques and the emotional data acquisition method used, while Section 4 describes our Multi-Relational and Emotional approach to predicting student performance. Section 5 presents an evaluation of this approach and provides a comparative study of our results with those of State-of-The-Art. Section 6 concludes this paper.

II. State-of-the-Art

Personalized learning improves not only the learning process itself but also the overall learning outcomes [7] [8]. But this personalization is only possible by adapting the content of the learning and applying a learning strategy adapted to each individual. Also, with regard to current ITS, it is necessary to have, on the one hand, relevant information on student and, on the other hand, to predict his performance at each stage of his learning. A great deal of research on student performance predicting is available in the associated scientific literature. Student performance prediction is carried out according to several attributes and methods. The choice of selected attributes and the choice of methods used are decisive for predicting performance, in precise evaluation frameworks. In [9] [10] [11], for example, authors chose attributes such as internal marks, session marks, admission score and students' activities by applying decision trees. Raheel Asif *et al.*, [10] showed that using this approach, we could achieve a performance prediction accuracy of around 83.65%. Other authors such as Abu Amra *et al.*, [12] extended the choice of attributes to the student's father work, the student's place of residence, the gender, and the past performances by applying two different types of classification algorithms: K-Nearest Neighbors (KNN) and Naïve Bayes. Experimental results have shown that the Naïve Bayes method is better than the KNN method with an accuracy of 93.6%. Okubo *et al.*, [13] proposed a Recurrent Neural Network (RNN) approach to predict students' final grades from journal data stored in education systems.

Besides, several other studies such as that carried out in [14] [15] [16] rather propose methods of Data Mining making it possible to search for attributes which significantly affect student performance. Shana *et al.*, [14] for example have extracted, by applying two statistical techniques which are Pearson correlation coefficient and Fisher test, attributes such as previous school marks, level of difficulty of the subject, income family and the student's interest in the subject. Havan Agrawal *et al.*, [15] showed on the basis of a Neural Network model that the current students' academic performances depends mainly on their past performances. The authors Haixia Lu *et al.*, [16] proposed an algorithm for characteristics (attributes) selection which uses Pearson correlation coefficient and Euclidean Distance to measure the correlation between characteristics. The selected characteristics include, among others: past marks, number of school absences, student's willingness to pursue higher education, student age, number of past failures. In [17] the authors compare the results of the two classifiers Support Vector Machine (SVM) and KNN on the data set provided by the University of Minho in Portugal, in order to predict student's final grade. The data set concerns students' mathematical performance and consists of 395 data samples. Characteristics selection was done by calculating the correlation between each attribute (33 Attributes in all) and the target variable (which is the final score). Empirical studies results have shown that the SVM algorithm performs slightly better than the KNN algorithm. The author Seifedine Kadry [18] has shown through a linear regression analysis that the independent variables studied: height, weight, IQ score, sex and age of a student have no significant impact on the performance of it. But the revision time has a significant effect on his performance on the exam.

Other studies such as those conducted in [19] [20] have used Matrix Factorization, a technique derived from recommendation systems to predict students' performance. The results of these studies have shown that the use of this technique can improve prediction results compared to regression methods by building on the student's past performance. Other authors have proposed improving this method by exploring multiple relationships that may exist between students, tasks and their metadata using Multi-Relational Matrix Factorization (MRMF) and Weighted Multi-Relational Matrix Factorization (WMRMF) models [21]. In [22] we proposed a Social and Weighted Multi-Relational Matrix Factorization model which integrates not only friendship relationships like group work relationships, but also mutual influence values to favor error reduction in student performance prediction.

It is clear from this literature review that the majority of research has relied mainly on socio-economic factors and on student past skills without taking into account of emotional aspect. That is constitutes the object of our present study.

III. Methodological Approach

Our approach combines a Weighted Multi-Relational Matrix Factorization model and a Multiple Linear Regression modelling Emotional Impact. Therefore, this session presents some Matrix Factorization approaches as methods that we will use to describe and compare our proposed approach. In addition, it presents the method of self-assessment of emotions through the concept of Achievement Emotions.

A. Matrix Factorization Approachs

1) Classical Matrix Factorization (MF) approach: Consider a set S of students, a tasks set I , and a range of possible performance scores P. Matrix Factorization consists in approximating a matrix R by a product of two matrices W_1 (Students) and W_2 (Tasks) [22] [23] [24] as described by (1)

$$R \approx W_1 \, W_2^T \tag{1}$$

$W_1 \in \mathbb{R}^{S \times F}$ is a matrix where each line *s* is a vector containing the *F* latent factors describing the student *s* and $W_2 \in \mathbb{R}^{I \times F}$ is a matrix where each line *i* is a vector containing the *F* latent factors describing the task *i*. Let w_{1_s} and w_{2_i} be the respective vectors of the matrices W_1 and W_2 such that their elements are designated by $w_{1_{sf}}$ and $w_{2_{if}}$.

In this method, a student *s* performance in accomplishing a task *i* is predicted by (2) :

$$\hat{p}_{si} = \sum_{f=1}^{F} w_{1_{sf}} \, w_{2_{if}} = w_{1_s} \, w_{2_i}^T \tag{2}$$

$\hat{p}_{si}$ is the predicted performance value.

W_1 and W_2 designate the model parameters and can be learned by optimizing (3) using Stochastic Gradient Descent method as suggested in [25].

$$O^{MF} = \sum_{(s,i)\in R} \left(R_{si} - w_{1_s} w_{2_i}^T \right)^2 + \lambda \left(\| W_1 \|_F^2 + \| W_2 \|_F^2 \right) \tag{3}$$

The symbol $\| \, . \, \|_F^2$ indicates the Frobenius norm and λ is a regulation parameter [26]. Let e_{si} denote the difference between the real performance value and the predicted performance value for each couple (*Student*, *Task*). the prediction error is given by (4) :

$$e_{si} = \left(R_{si} - w_{1_s} w_{2_i}^T \right) \tag{4}$$

2) Multi-Relational Matrix Factorization (MRMF) approach: Unlike the MF model, the MRMF model refers to

N types of entities $\{E_1,...,E_N\}$ connected by M types of relationships $\{R_1,...,R_M\}$ that can be strongly correlated with each other. Let $W_1,W_2,...,W_n$ ($n \in N$), be the latent factor matrices (designating the parameters of the model) of each of entity types. Equation (3) thus becomes (5) [26] [21] [27]:

$$O^{MRMF} = \sum_{r=1}^{M} \sum_{(s,i)\in R_r} \left(R_{r_{si}} - w_{r1_s} w_{r2_i}^T \right)^2 + \lambda \left(\sum_{n=1}^{N} \| W_n \|_F^2 \right) \quad (5)$$

With $R_r = \{(E_{1r}; E_{2r})\}(r = 1...M)$

3) Weighted Multi-Relational Matrix Factorization approach (WMRMF): The WMRMF model incorporates a weight factor which gives the importance of one relation compared to another.

Equation (5) thus becomes (6) [21] [27] [28]:

$$O^{WMRMF} = \sum_{r=1}^{M} \Theta_r \sum_{(s,i)\in R_r} \left(R_{r_{si}} - w_{r1_s} w_{r2_i}^T \right)^2 + \lambda \left(\sum_{n=1}^{N} \| W_n \|_F^2 \right) \quad (6)$$

With: $$\Theta_r = \begin{cases} 1, & \text{if } r \text{ is the main relation} \\ \theta, & si \ (0 < \theta < 1) \end{cases} \quad (7)$$

The model parameters are updated through (8) and (9).

$$w'_{r1_{sk}} = w_{r1_{sk}} + \beta\left(2\Theta_r e_{r_{si}} w_{r2_{ik}} - \lambda w_{r1_{sk}}\right) \quad (8)$$

$$w'_{r2_{ik}} = w_{r2_{ik}} + \beta\left(2\Theta_r e_{r_{si}} w_{r1_{sk}} - \lambda w_{r2_{ik}}\right) \quad (9)$$

The parameter β designates the learning rate.

B. Achievement Emotions

In our Multi-Relational approach, we suggest taking into account the possible emotions felt by students during the evaluation sessions. The consideration of emotions suggests, beforehand, the choice of a category of candidate emotions and the choice of a method of emotional detection.

In context of emotions candidate selection, several research studies have generally focused on those related to learning but in particular on those related to learning evaluation [29] [30]. The aim of this work was, through theoretical and statistical studies, to research different emotions that are aroused in a learning context.

In this study, we based on Pekrun's [31] control-value theory of achievement emotions.

The theory proposed by Pekrun strives to provide an integration framework for analyzing the antecedents and effects of emotions experienced in achievements in an academic environment. These emotions are also called achievement emotions. They occur in different academic contexts such as taking courses, studying and taking tests / exams [32]. Achievement emotions are considered to be emotions directly related to achievement activities and / or achievement outcomes [33] [29]. These activities refer to tests, assignments and performances both in examination conditions and as mere tasks, whereas achievement outcomes refer to for instance grades and scores [34]. Empirical evidence from Pekrun's theory indicates that achievement emotions have three dimensions [34]:

- Valence (positive / pleasant versus negative / unpleasant);
- Activation (activation versus deactivation);
- Focus on the object (activity versus outcome).

The control-value theory of achievement emotions considers the emotions like sets of interdependent psychological processes, according to which the affective, cognitive, motivational and physiological components are of first importance [32].

In our approach, due to the complexity of emotion detection linked to the test, we used the self-assessment method based on Achievement Emotions Questionnaire (AEQ) to detect students' emotions. The AEQ was developed by Pekrun and his colleagues [32]. It is a self-assessment tool for measuring students' emotions in school situations. The instrument, in its final version, consists of 24 emotion scales which are organized into three sections evaluating both class-related, learning and test-related emotions [32]. The AEQ is made up of 232 items that measure eight different emotions related to the class, eight emotions related to studying, and eight emotions to writing tests and exams. A 5-point Likert scale (1 for completely disagree and 5 for completely agree) is used to assess the emotional experiences of students. The emotional scales related to the test include 77 items and the instruction asks students to indicate what they feel in terms of enjoyment, hope, pride, relief, anger, anxiety, shame, and hopelessness related to the test. These eight emotional scales are those chosen by our approach.

IV. Proposed Prediction Approach

In this section, we present our approach or predicting student performance that takes into account student's emotional state. Fig. 1 presents, in entity-association diagram form, the information taken into account by our model.

A. Problem Formulation

The student performs a task by associating a performance score and the emotions associated with the execution of the task (emotions recovered using the AEQ).

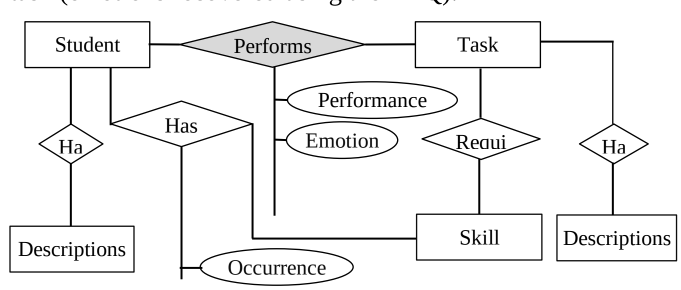

Fig. 1. Entity-Association Diagram for Predicting Student Performance.

Solving correctly the task, student must know specific skills, and task itself is also associated with the skills to be learned by student. The attribute "Occurrence" gives the number of times student has learned the skill.

B. Emotional Influence Formulation ε_{si}

We hypothesize that any task accomplishment is always accompanied by one or more well-given emotions. We adopt the principle that a student's performance depends not only on their intrinsic abilities (cognitive abilities), but also on his emotions experienced impact.

Note ε_{si} , the emotional impact on the student's performance in completing task *i*. In our approach, ε_{si} is defined as a Multiple Linear Regression model which establishes a linear relationship with the different test emotions of AEQ, relative to task *i*. The different values taken by ε_{si} are reals included in interval $[-1;1]$. The different coefficients are elements of matrix $\alpha=(\alpha_1,\alpha_2,...,\alpha_8)$. The different variables are elements of matrix $e=(e_1,e_2,...,e_8)^T$. These elements are respectively the intensities of the eight scales of emotions linked to the test which are: enjoyment, hope, pride, relief, anger, anxiety, shame and hopelessness, and are collected using of the AEQ. Table I presents the different variables and descriptions of variables as proposed.

The different values $e_1,e_2,...,e_8$ are easily obtained using AEQ. So, we formulate model ε_{si} as follows:

$$\varepsilon=\alpha.e+\alpha_0 \tag{10}$$

The model ε_{si} was developed on the basis of data collected during the AEQ survey. Unlike the work done in [21], we consider emotion as an additional entity type. Indeed, the relation « *Student – Performs – Task* » does not only take into account performance, but also the possible associated emotions and their valences (Fig. 2).

This relationship generates two matrices: the performance matrix and the emotional impact matrix. The emotional impact matrix has the same dimension as the performance matrix as shown in the example in Fig. 3. In this example, we notice that student S_4 performed task T_5 by obtaining the score of 1. The emotional impact factor on performance, on task T_5 completion is $\varepsilon_{45}=0.8$. We consider this value as the contribution of emotions to task T_5 achievement. This contribution can either favor task accomplishment, or disadvantage it.

TABLE I. VARIABLES DESCRIPTION IN MODEL ε_{si}

Variables	e_1	e_2	e_3	e_4	e_5	e_6	e_7	e_8
Intensity of :	Enjoyment	Hope	Pride	Relief	Anger	Anxiety	Shame	Hopelessness

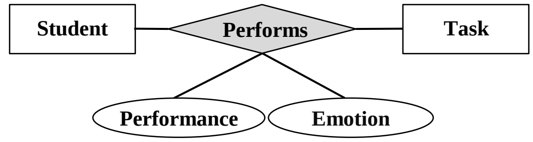

Fig. 2. Relation « Student – Performs – Task ».

In our approach, we combine model ε_{si} with the MRMF and WMRMF models, through the iterative algorithm 1.

P	T_1	T_2	T_3	T_4	T_5
S_1	1			0	1
S_2	1	1		1	
S_3		0	1		
S_4	1			1	1
S_5			0		0

ε	T_1	T_2	T_3	T_4	T_5
S_1	0.7			0.4	0.7
S_2	0.6	0.9		0.9	
S_3		0.3	0.5		
S_4	0.7			0.7	0.8
S_5			0.9		0.1

Fig. 3. Performance Matrix (P) and Emotional Impact Matrix (ε)

To determine optimal parameters $W_1,W_2,...,W_n$ of this approach, we proposed the iterative algorithm 1 below using a Stochastic Gradient Descent.

Algorithm 1

Input

N *: number of entities;* M *: number of relations ;* F *: number of latent factors ;* R_r *: for each relations ;* θ *: weight ;* λ *: regulation term ;* β *: learning rate ;* K *: Latent factors.* α_1, α_2, α_3, α_4, α_5, α_6 α_7, α_8 *: respectively emotions Enjoyment, Hope, Pride, Relief, Anger, Anxiety, Shame and Hopelessness factors.*

Output

$\{W_j\}_{j=1...N}$ *: latent factor matrices for each entity j*

Initialize W_j *for each of the* N *entities using* $N(\mu,\sigma^2)$
Initialize Θ_r *for each of the* M *relations*
Initialize ε_{si} via (10)
While (Stopping criterion is not met) **do**
 for each relation $R_r=\{(E_{1r};E_{2r})\}$ *in* $\{E_1,...,E_M\}$ ***do***
 for *s* = 0 to number of rows-1 of R_r ***do***
  for *i* = 0 to number of rows-1 of R_r ***do***
  $e_{si}=R_{si}-\hat{p}_{si}$
  for *k* = 0 to *K*-1 ***do***
  $W_1[s][k]\leftarrow W_1[s][k]+\beta(2\Theta_r e_{si} w_{r2_{ik}}-\lambda w_{r1_{sk}})$
  $W_1[s][k]\leftarrow W_1[s][k]+\beta(2\Theta_r e_{si} w_{r2_{ik}}-\lambda w_{r1_{sk}})$
  end for
  end for
 end for
 end for
end while
Return $\{W_j\}_{j=1...N}$

This algorithm proceeds first by initializing the parameters from the normal distribution $N(\mu,\sigma^2)$, taking for expectation $\mu=0$ and for standard deviation $\sigma=0.01$. Numerical simulation through Algorithm 1 also makes it possible to determine the optimal values of matrix $\alpha = (\alpha_1, \alpha_2, ..., \alpha_8)^T$ parameters. These values are also those which minimize (6).

V. Evaluation of Proposed Approach

In this section, we evaluate our proposed approach in order to show its effectiveness in reducing errors in student performance prediction. We also perform tests to compare our approach performance with certain methods in the literature.

A. Participants and Procedure

To evaluate our emotional modelling approach and study the effect of taking emotion into account in student performance prediction, we carried out studies on upper secondary learners of general education, enrolled in class of Terminal at Lycée Moderne Khalil (Daloa, Côte d'Ivoire). The data were collected by means of the questionnaire distributed to the voluntary student to participate in this research. The sample consisted of 250 students (80 girls with an average age of 16; and 170 boys with an average age of 17). These students were assessed during exams in several disciplines: Mathematics, French, English, History and Geography, Philosophy and Biology Science, for the 2019 - 2020 school year from January to February. The questionnaire was filled out several times for each test in the exam. For our model evaluation, we used the eight emotion scales linked to the AEQ tests. These scales are composed of four emotions with positive valence and four emotions with negative valence.

B. Results and Discussion

We implement two types of models. The first is a Multi Relational and Emotional model noted Emo-MRMF and the second is a Weighted Multi Relational and Emotional model noted Emo-WMRMF. For the evaluation, we reduced the model ε_{si} to three scales of test emotions: Enjoyment, Hope and Anxiety. Indeed, positive activating emotions such as enjoyment and hope can lead to better performance results [35] while negative emotions such as anxiety can lead to poorer performance results when triggered [36]. In [30] [37] the authors have shown that positive emotions such as enjoyment and hope are generally positively correlated with test scores and results. The scale model looks like this:

$$\varepsilon_{si} = \alpha_0 + \alpha_1 e_1 + \alpha_2 e_2 + \alpha_6 e_6 \tag{11}$$

The working environment used for simulations is a 64-bit operating system computer, 8GB of RAM, intel Core i7. The Algorithm 1 development was done in Python language.

To compare our Emo-MRMF and Emo-WMRMF approaches to the MF, MRMF, WMRMF, Global Average, Item Average and User Average methods, we used the RMSE (Root Mean Squared Error) metric. This metric is calculated as follows:

$$RMSE = \sqrt{\frac{\sum_{(r,s,i)\in D^{test}} (p_{si} - \hat{p}_{si})^2}{|D^{test}|}} \tag{12}$$

For referencing, we report the best hyperparameters that we found via cross-validation in Table II.

The experimental results presented in Fig. 4 show that our Emo-MRMF and Emo-WMRMF approaches significantly improve the MFMF and WMRMF approaches by taking into account multiple relationships and the emotional impact factor. The Emo-WMRMF model gives very good results in terms of RMSE reduction compared to simulated comparative methods. Our results show the importance of taking into account emotions in the field of learning in general and in particular in the prediction of student performance. These results also show that emotions have an influence on cognitive abilities such as problem solving and decision making as suggested by Lois Isenman [38]. These results demonstrate the robustness of Multi Relational Matrix Factorization models to ingest a variety of information and relationships.

TABLE II. Optimizing Hyperparameters

Methods	**Parameter**
MF	$K=2$; #iter = 320 ; $\beta = 10^{-3}$; $\lambda = 0.15$
MRMF	$K=2$; #iter = 320 ; $\beta = 10^{-3}$; $\lambda = 0.1$;
WMRMF	$K=2$; #iter = 320 ; $\beta = 3.10^{-3}$; $\lambda = 75.10^{-4}$; $\theta \in \{1.0; 0.80; 0.70\}$
Emo - MRMF	$K=2$; #iter = 320 ; $\beta = 10^{-2}$; $\lambda = 55.10^{-3}$; $\alpha_1 = 14.10^{-3}$; $\alpha_2 = 22.10^{-3}$; $\alpha_3 = -33.10^{-3}$, $\alpha_0 = 0$
Emo-WMRMF	$K=2$; #iter = 320 ; $\beta = 3.10^{-3}$; $\lambda = 15.10^{-4}$; $\theta \in \{1.0; 0.40; 0.80; 0.70\}$; $\alpha_1 = 3.10^{-3}$; $\alpha_2 = 2.10^{-3}$; $\alpha_3 = -3.10^{-3}$; $\alpha_0 = 0$
Emotional Impact	$K=2$; #iter = 320 ; $\beta = 3.10^{-3}$; $\lambda = 15.10^{-4}$; $\theta \in \{0.7; 1.0; 0.60; 0.40\}$; $\alpha_1 = 5.10^{-3}$; $\alpha_2 = 25.10^{-3}$; $\alpha_3 = -23.10^{-3}$

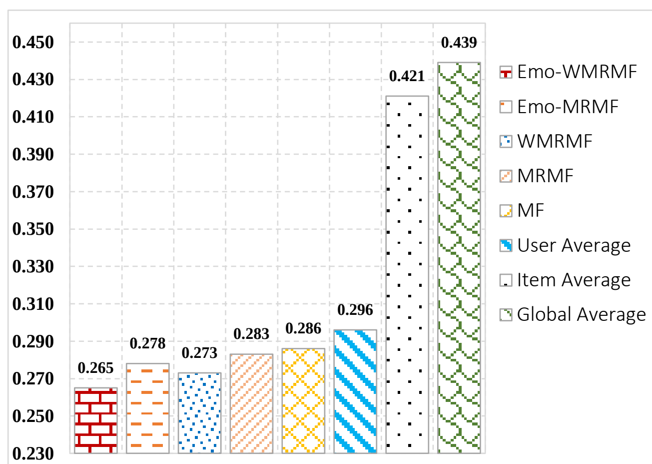

Fig. 4. RMSE Results on our Data Set.

Fig. 5 shows the RMSE results of Emotional Impact factor prediction for different values of parameter iteration. Indeed, the optimization of the model allows, of course, to predict performance, but also to predict the emotional impact of a student *s* when carrying out a task *i*. When the number of iterations tends to around 320, the RMSE error in predicting emotional impact tends to around 0.232. This reveals the robustness of MF Models to predict all kinds of attributes of the application domain.

Fig. 5 also presents the RMSE evolution of the Emo-WMRMF model. The emotional impact prediction curve decreases rapidly to 80 iteration steps and remains practically constant up to 320. This shows that our model is robust already with an iteration number of 80.

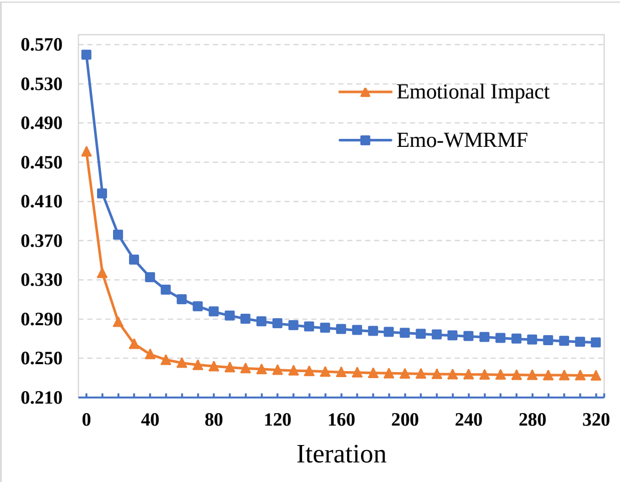

Fig. 5. RMSE with different Values of Iterations.

VI. Conclusion

In this paper, we have proposed an approach which aims at providing a solution to student performance predicting problem in ITS by combining Multiple Linear Regression (modelling Emotional Impact) and a Weighted Multi-Relational Matric Factorization model to take advantage of both student cognitive and emotional faculties. This approach takes into account not only the relationships that exist between students, tasks and skills, but also their emotions. Experimental results on a set of data collected in a general secondary school have shown that our approach makes it possible to more accurately predict student performance.

In future work, we plan to study the impact of the emotional state evolution during assessment sessions and analyze the effect of other emotional scales on student performance prediction results.

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Applying Aspect Oriented Programming in Distributed Application Engineering

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***Abstract*—Aspect-oriented programming is an emerging programming paradigm that stretches during the development phases in different domains. Many researchers have focused on the use of this paradigm in web service composition in different research axis. However, none of them use together aspect-oriented programming and design by contract to deal with the adaptation of the parameters in the web service composition process. This paper proposes a web service composition algorithm based on the planning graph using both Aspect-oriented programming and design by contract concept. The aspect-oriented Programming approach provides explicit support for separation of crosscutting concerns in web services composition whereas the design by contract approach allows the processing of parameters execution in pre-condition and post-condition mode by using contracts in order to ensure correct service execution with adaptation to external parameters without touching in properties which can be dealt with re-construction of the composite service. Future development of this planning graph will include the introduction of the dynamic way of aspect oriented programming and add comparison results.**

Keywords*—*Aspect oriented programming; design by contract; web service composition; parameters adaptation

I. Introduction

Aspect-Oriented Programming (AOP), is a new programming paradigm introduced in information systems, presents a new element called aspect, in order to encapsulate the crosscutting concerns of the program. Instead of having one concern repetitive in multiple code blocks, the aspect can represent all these concerns in a single code block completely separate from the source code [8].

The aspect contains three main elements, a joinpoint, a pointcut, and advice. AOP also introduces the notion of a weaver. Weaving behavior is the process that allows weaving the program with these different aspects [3, 4].

Some researchers have focused on applying AOP technologies into the Web service composition domain. Their researches goals were situated around the increase in the adaptability of web service [17] or modularize crosscutting concerns in web service composition [10].

However, no one of them has treated the problem of parameter adaptation and conflict between the services during the composition phase by the mean of AOP and design by contract.

The Design by Contract (DbC) is an approach that uses a contract to specify and define the mutual obligations and expected parameters of the communication between services composite process, and use assertions to check whether an application complies with a contract. The failure of an assertion is typically a symptom of a bug in the software. There are three different kinds of assertions [5, 7]:

1) Pre-conditions: specifies parameters conditions that must hold before an operation executes.

2) Post-condition: specifies parameters conditions that must be hold after an operation completes, consequently, post-condition is evaluated after a method completes.

3) Invariant: specifies a parameters condition that must be hold anytime when a client invoke an object's method.

The work in this paper proposes a web service composition algorithm based on the planning graph using both AOP and DbC to deal with the problem of parameter adaptation and conflict in web service composition using separation of crosscutting concerns.

Remind that web services are applications available on the internet, each of them performs a special task [1].

Except that, the requirements of the client always exceed the demand of a single request or a single task, for example, if the client wants to afford a holiday, he desires to find a web service that offers him in the same time, purchase of a plane ticket, hotel reservation, and car reservation, and other.

As no specific web service can meet all of these requirements at the same time, it should be possible to combine several existing services to fulfill one's needs. This is the composition of web services. However, one of the important issues to be addressed in the composition of web services is that some services impose certain input or output parameters that are defined by their suppliers and/or imposed by their clients. These constraints specify the conditions that must be met to ensure correct execution or appropriate interaction with the different services involved in the composition.

In this context, the main contributions of our research work are focused on:

Applying the AOP paradigm into web services composition to increase the adaptability of services and to modularize crosscutting concerns. When crosscutting concerns are separated from the code of each service, it becomes easy to modularize the crosscutting concern of the composite service and then monitoring these parameters as discussed by Sk. Riazu Rahemana et al. in [9, 20].

On the other hand, we have applied the DbC paradigm for safer interaction between input parameters of each new service which is added to the composition and the output parameters of the composite service belonging in web services composition to avoid conflicts and exceptions.

The remainder of this paper is structured as follows:

Section 2 reviews related work, Section 3 presents the conceptual architecture. In Section 4 an example is given. Finally, Section 5 concludes the paper.

II. Discussion and Related Work

Many types of research corresponding to the web service composition have been published in recent years. They revolve around different areas of research. We focus on those who used the AOP.

Various studies have been made concerned applying AOP in web services composition like those in [9, 10, 11, and 12].

Charfi and. al. has approached this problem from a different direction. They have proposed an extension to the BPEL language, which they called aspect-oriented BPEL (AO4BPEL). Their language brings in modular and dynamic adaptability to BPEL [15] However, they do not pay attention on the issue of the crosscutting concerns consisted in service compositions.

Both of [10], [11] propose a method for decoupling security concerns in Web services via aspects, by expressing these concerns as contextual information separate from the core Web services functionality.

Authors in [12] have proposed a formal method through a Petri net-based algebra for aspect-oriented web service composition. The formal semantics of the composition operation including composition operation for modeling basic compositions and crosscutting operation for modeling aspects is expressed in terms of Petri nets.

In [16] the authors used distributed aspect-oriented programming (AOP) technology to model an adaptive architecture for Web services composition, by representing the non-functional properties of each Web service - composite and component - via AOP. They make a relation function between the aspects of the composite web service and the individual aspects of the component Web services.

In [17] authors proposed a method to increase the adaptability of web service by using the main AOP agreed semantics.

In [18] an approach that have brings design by contract to Web services has been presented. Authors have elaborated generic solution architecture, and define its components and have investigated the foundations such as important guidelines for applying design by contract.

In [2, 19] authors have proposed a graph plane based approach model and detect composition conflicts related to introduction (structural composition).

In [13] authors have applying design by contract an Aspect Composition.

However, none of these approaches have been applying both AOP and DbC in the same context of web service composition. Thereby this paper is the first attempt at using both the AOP approach and DbC benefit in web service composition focused on parameter adaptation.

III. Conceptual Architecture

A. Concepts and definitions

When crosscutting concerns are separated from each service in a web services composition, a service composition can be seen as a result of a composite web service weaved with aspects and contracts.

This section of the paper will describe web service composition algorithms based on the planning graph construction. On giving first certain definitions below.

- Definition 1

L is the set of different available services participating in the composition of web services. L= {S1, S2, S3… Sn}

And Si is a service number i defined by Si=<Pi.I, Pi.O, Cc>

- Pi.I is the input parameters of the service i
- Pi.O is the output parameters of the service i
- Cc is a list of the crosscutting concerns (scattered or tangled codes) requirements of the service.

- Definition 2

R is the set of different Aspect, R= {A1, A2, 3… An}

A is an Aspect defined by

A=<Cc, Joinpoint, Pointcut, Advice>

Where,

- Cc: crosscutting concern functionality.
- Advice: is a workflow code that encapsulates Cc.
- Joinpoint some points in the program of the service related to pointcuts of the aspect.
- A pointcut is a function that relates a joinpoint to a set of advice.

There are three sorts of pointcuts:

- A before pointcut Si.Cc⤵A.advice, represent that advice is executed before the execution of the service i.
- An after pointcut Si.Cc⤴A.advice , represent that advice executed after the execution of the service i.
- An around pointcut Si.Cc⤴⤵ A.advice , represent that advice executed around execution of the service i.

If an aspect A.advice crosscuts a crosscutting concern of a service S, it gives us: Si' = Si ◁ A, which represents that the service Si, is weaved with aspect A.

- Definition 3

We define Db as a Boolean contract relationship between the output and input parameters of two layers successive in the Graph, given by:

Db⟨type, Si.Output parameters, Si+1.Input parameters⟩.

Where type can take three formats:

- @Pré (a precondition of the contract): specify a contract that must hold before the execution of the input parameters of the service Si.PI.
- @post (postcondition of the contract): specify a contract that must hold before the execution of the input parameters of the service Si.PI.
- @Inv (invariant): specifies a contract that must behold any time when service features are invoked.

Several cases are treated:

- If ($Si.PI \cap Si+1.PO = \emptyset$) then

  Db (@Pré, Si.PI, Si+1.PO) = true

If this condition is satisfied we have: $S= S1 \perp S2$

$S1 \perp S2$ represents a composite service S that results from performing the service S1 followed by the service S2, S1 must be completed before S2 can start.

- if ($Si.PI \cap Si+1.PO = \emptyset$) then

  Db (@Post, Si.PI, Si+1.PO) = true

  In this case, we have: $S= S1 \vdash S2$

$S1 \vdash S2$ represents a composite service S that results from performing unordered between S1 and S2, the service S1 followed by the service S2 or S2 followed by S1

- if ($Si.PI \cap Si+1.PO = \emptyset$) then

  Db (Inv, Si.PI, Si+1.PO = true

In this case, we have: S1|| S2 represents a composite service S, which results from performing in parallel service S1 and/or service S2.

- Definition 4

We define the composite web service request as a tuple:

REQ= <L, R, Db> where:

- PI: is the set of the input parameters that the client can provide.
- PO: is the set the output parameters expected by the client.
- PE: is the set of constraints representing required limitations on input and output parameters, as required by the client.

B. *Proposed Algorithm*

This section describes the algorithms for constructing web services composition based in a planning graph (see Fig. 1), applying aspect-oriented programming and contracts techniques.

Our planning graph is a horizontal directed layered graph in which the jump to the next node is permitted only from one node layer to the next.

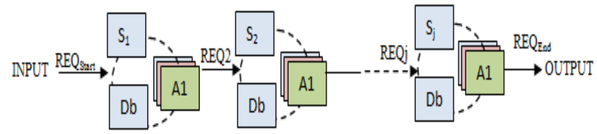

Fig. 1. A Planning Graph of the Web Services Compositions.

The node in level 0 corresponds to the REQStart

- REQStart is the node input of the graph which includes specifications and parameters given by the client in the composite web service; it's the Composition start request.

REQStart <L, R, Db> = INPUT request= {specification set of the client}

The node in level i depends on the composite service got from on the result of the layer i-1, who will be in turn submitted to the action of the REQi by weaving the aspects required and by applying the necessary contracts.

REQi <{Si-1,Si}, R, Db>

- REQEnd is the last node of the graph which give the composition plan (algorithm 3) result that must accomplish the client requirements as specified in the INPUT request.

REQEnd is the OUTPUT request which gives us as a result the composition plan.

Algorithm1. Services composition algorithm

INPUT: REQstart⟨ Composition request start ⟩, L⟨ Set of available services ⟩, R⟨Set of Aspects⟩, Db⟨ relation of Contract ⟩, n (maximum numbers Service available in L)

OUTPUT: GraphPlan (REQEnd or failure)

```
Graphplan=null;InputParameters =REQstart.PI
n = ∑service ∈ L
Si' =null
for i=1 to n do
L=i
for each Service Si ∈ L do
if (Si.PI⊂ Inputparameters) and (Si ∉ grapheplan) then
for each A ∈ R do
if (Si.Cc = A.Cc) then
addAspect(Weaved, Si, A)
end if
end for
OutputParameters=OutputParameters ∪ Si.PO
AddService(REQ L, Si',Si)
Graphplan= Graphplan.proceed
REQi = REQi+1
end if
i=i+1
end for
Graphplan= Graphplan.Completed
return failure
```

The Algorithm 1 gives the composition service model based on the graph plan, the expected result is the service composite that accomplish all specifications given by the client.

Our service composition approach use aspect oriented programming method to solve problems of crosscutting concerns that target services, and design by contract to give order of performing parameters between services.

The composition service model begins with REQstart, which gives input parameters according to the specifications required by the client. , in the composition process graph, each service belongs to a layer level inside the graph where a new REQ of the same level is generated (line 16).

Each service in the level layer will be woven with all crosscutting concerns which are separated and encapsulated in aspects (line 10) with function addAspect given in algorithm 2.

A contract relation is done between the output and input parameters of services in two layer.

The service will itself be inserted afterwards in the graph (line 14) given in algorithm 3.

Algorithm 2. AddAspect

INPUT Weaved(service weaved with aspect),
Si (Service Si), A (Aspect)

OUTPUTSi (Si′; Si weaved with the Aspect A)

1: A.jointput → Si.Cc (Si.Cc is advised jointput)
2: if A.advice related to Si.Cc befor then
3: Si.Cc⤵A.advice (relates A.advice to an
advised joinpoint)
4: else if A.advice related to S.Cc after
then Si.Cc⤴A.advice
5: else Si.Cc ⤵⤴A.advice
6: end if
7: end if
8: Si′ =Si ◁ A

In AddAspect (algorithme 2) an advised jointput in a service will be weaved with the advice of the aspect (line1).

Since we have working with the aspectJ the advice can be executed before the pointCut (line 2-3) or after (line 4) or around (line 5). In the end we have a new service generated from the weaving.

Algorithm 3. AddService

INPUT REQ L (L is the number of the index layer in the GraphPlan)

Si (the new service to be added to the graph plan)

Si’ (the product composite service by the previous layer)

OUTPUT REQ L+1(next request), Si″ (the product composite service by the current layer)

1: while (Si.PI ≠Ø) do
2: if Db(@pré, Si’.PO, Si.Pi)) =true then
Si″ = Si’⊥ Si
3: else if Db(@pro, Si’.PO, Si.Pi)) =true then Si″ = Si’⊦ Si
4: else Si″ = Si’||Si
5: end if
6: end if
7: GraphPlan=GraphPlan ∪ Si
8: end while
9: Si’ = Si″
10: L =L ∪ Si″
11: return GraphPlan

Algorithm 3 adds a new service Si to the set of services composite which are itself only a single service Si’, these two services undergo a contract test based on their output and input parameters. This test defines the way to perform these two services in a given layer of the planning graph belonging to a given request line (line 6-10).

(Line 6) represents a new service composite Si″ that performs the previous service composite Si’ followed by the service Si, Si must be completed before Si can start.

(Line 7) represents a new service composite Si″, that performs unordered between the previous service composite Si’ and the service Si, the service Si’ followed by the service Si, or Si followed by Si’.

(Line 8) represents a new service composite Si″ that performs the previous services composite Si’ and the service Si independently from each other.

At the end, the new service composite generated is included in the set of services L and added to the graph.

IV. An Example

This section, an example is given to better describe the proposed planning graph. Consider for example a basic version of shopping application that consists of the following sequence of tasks: Searching for products, submitting an order, Paying for the order, and shipping of the order (see Fig. 2).

The planning graph is assembled from the uses of these different available services:

- S1 offer the Search service,
- S2 offer the Order service,
- S3 offer the payment service
- S4 offer shipment service

Instead of the client using a single web service for each service they want to achieve (Search service, Order service, payment service, shipment service), it would be better to offer him a single service that meets all these requirements; it is the composition of Web services.

The Web service composition can be mapped to a planning graph (see Fig. 2) as follows:

The Search service, Order service, payment service, shipment service are the four Web services required by the client, which form the set L.

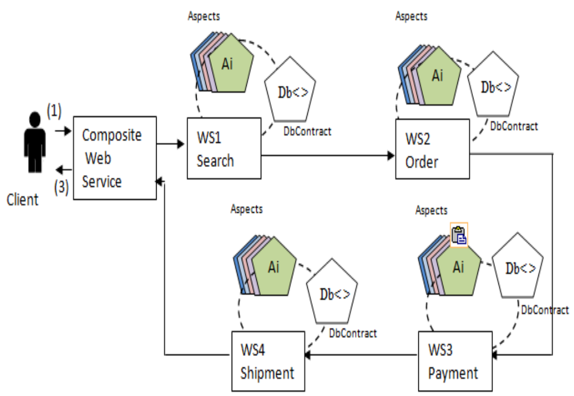

Fig. 2. The Planning Graph of the Example.

If we consider that each of the service mentioned before shares some crosscutting concerns, which will be defined as modules called aspects, cited below:

- Maintaining the history of the client, for future purchase {Aspect1 =History }
- Only authenticate client are allowed to effect the payment service

  {Aspect2 =Authentication}
- Ensuring the confidentiality of the client information about his bank account

  {Aspect3 =Security}
- Accommodate the timing property in order to calculate the time taken by the client to access the Web services, to be sure that the answer to the client request was not long {Aspect4 =Timing}

So we have:

L= {S’= null, S1=Search, S2=Order, S3=Payment, S4=Shipment}

And R= {A1=History, A2=Authentication, A3=Security, A4=Timing}

Supposing that input and output parameters for these services are:

- Search.PI={ProductNumber, DeliveryAddress }, Search.PO={ProductNumber, Product Address }
- Order.PI= {PaymentAmount, PaymentMethod}, Order.PO= {OrderNumber, PaymentAmount}
- Payment.PI ={ProductNumber }, Payment.PO ={PaymentConfirm}
- Shipment.PI= { PaymentConfirm, DeliveryAddress, Product Address, OrderNumber, ShippmentConfirm } , Shipment.PO= {ShippmentConfirm }

And the specification parameters required by the client are: PE = {C1, C2, C3} where:

C1 = ProductAdress ∈ {Europe}

C2= DeliveryAdress ∈ {Europe}

C3= PaymentMethod ∈ {visa, MasterCard}

The first request REQ1 is between S’ (he is null because we haven't started the composition of the services yet) and S1 (search article service), the only aspects that crosscut these services are A1and A4 and they crosscut all the services, so we can wove him in the end of the composition processes. Let applying a contract relation:

Db (@Pré, S’.PO, S1.PI) = true

Ø∩ {ProductNumber, Product Address} ∈ PE

S´1= S’⊥S1

S1’.PO= {ProductNumber, Product Address ∈ {Europe} }

RES1<L, PI, PO, PE> where , L=L ∪ S1’, PO=

In the following request, S`1 will be perform with the service S2 and the contract relation is: Db (@Pré, S`1.PO, S2.PI) = true

{ProductNumber, Product Address ∈ {Europe}}∩ {PaymentAmount, PaymentMethod}, ∈ PE

S’2=S1’ ⊥ S2

S2’.PO= { ProductNumber, Product Address ∈ {Europe}, PaymentAmount,

PaymentMethod ∈ {visa, MasterCard}}

S´2= S`1⊥S2 = (S’⊥S1) ⊥ S2

In the next request, S`2 will be performing with the service S3.The Aspect A2 and A3 crosscuts S3 and the contract relation is: Db (@Pré, S`2.PO, S3.PI) ∈ PE

S’3= S`2 ⊥ S3

S’3.PO= { ProductNumber, Product Address ∈ {Europe}, PaymentAmount,

PaymentMethod ∈ {visa, MasterCard}, PaymentConfirm}

S´3= S`2 ⊥ (S3 ◁ A2 ◁ A3)

And in the last request, S`3 will be performing with the service S4.The Aspect A2 and A3 crosscuts S4 and the contract relation is: Db (@Pré, S`3.PO, S4.PI) ∈ PE

S´4 = S´3 ||S4◁ A1, A2, A3, A4

S’4.PO= { ProductNumber, Product Address ∈ {Europe}, PaymentAmount,

PaymentMethod ∈ {visa, MasterCard}, PaymentConfirm, ShippmentConfirm}

This example can be regarded as a woven composition service

S= (((S’⊥S1)⊥ S2) ⊥ (S3◁ A2 ◁ A3))|| (S4◁A2◁ A3))) ◁ A1, A4

Where,

S=<PI, PO, Cc>

PI= {PI.S1, PI.S2, PI.S3, PI.S4}

PO= S4'.PO

Cc= {A1.Cc, A2.Cc, A3.Cc, A4.Cc}

The planning graph of the example is shown in Fig. 3.

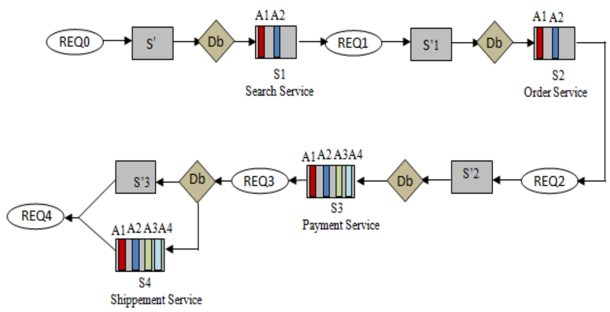

Fig. 3. The Composite Service of the Example.

V. Conclusion

The aim of this paper was the contribution of applying aspect-oriented programming in the web service composition domain with the use of the design by contract.

To this extent, we have proposed and illustrated algorithms based on the construction of a planning graph to eliminate the redundancy of the transversal codes of the crosscutting concerned in the various services belonging to the composition on the one hand and on the other to preclude conflict between parameters of the service composite generate from the web service composition process.

The planning graph using aspect-oriented programming and design by contract was introduced in our work to deliver a precise way to the web services composition without parameter conflict and without code redundancy.

We have shown that the proposed algorithms are suitable for the static detection of resolving conflict situations between parameters of services belonging to the composition.

We have implemented a web service composition prototype with eclipse and AspectJ [6] and a contract for java [14] that resolve conflict detection for each stage of the composition and for each service apart.

Using both AOP and Dbc as a planning graph technical for web services composition will certainly enhance web service composition quality in many ways including:

1) AOP offers better modularization in the web services composition domain, by gathering the crosscutting concerns of services that deals with the same aspect in one module avoiding the redundancy of crosscutting concerns in the composition.

2) AOP offers a consistent implementation in web services composition. Unlike traditional implementations of web services composition which are conspicuous in their inconsistency, AOP provides consistent implementation by having each aspect handled once and used in different web services sat the same time.

3) Moreover, AOP and Dbc are based on the same language and they are reusable and transferable. Therefore, developers don't need to learn more than one language.

4) Using DbC with AOP allows programmers to enforce a Boolean test of contracts and provide guidance in following best practices by creating reusable aspects without conflict and without exception.

We believe that this approach is general enough to be able to be used in all types of web service composition. We intend to use these two approaches together to explore the modeling and detection of constraints adaptation of parameters in the web services composition in our subsequent work.

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Object Detection using Template and HOG Feature Matching

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Abstract—**In the present era, the applications of computer vision is increasing day by day. Computer vision is related to the automatic recognition, exploration and extraction of the necessary information from a particular image or a group of image sets. This paper addresses the method to detect the desired object from an image. Usually, a template of the desired object is used in detection through a matching technique named Template Matching. But it works well when the template image is cropped from the original one, which is not always invariant due to various transformations in the test images. To cope with this difficulty and to develop a generalized approach, we investigate in detail another technique which is known as HOG (Histogram of Oriented Gradient) approach. In HOG, the image is divided into overlapping blocks of template size and then compare each block's normalized HOG with the normalized HOG of the template to find the best match of the object. We perform experiments with a large number of images and have found satisfactory performance.**

Keywords—Computer vision; template matching; HOG; feature extraction

I. Introduction

In order to reduce human sufferings and to speed up a specific task with more precision, we need to train a machine such that it can perform a specific task without any human interaction. The human eye can easily identify an object from an image; however, it is difficult for a machine to recognize the objects from an image automatically. If we want to recognize an object by a machine itself, we need to train the machine with an efficient object detection algorithm [1]. Therefore, the main objective of this research is to find out a better algorithm for machines to recognize objects in a scene. Here we are focusing on object detection using the template as well as HOG (Histogram of Oriented Gradient) feature-based techniques. The most widely used computer vision-based technologies are needed to resolve the problems of object matching and recognition in the field of image processing and analysis [2]. For any vision-based image processing application, object detection is the most integrated part [3]. An efficient object detection technique enables us to determine the presence of our desired object from a random scene, regardless of object's scaling and rotation, changes in camera orientation, and changes in the types of illumination. Template matching is one of the approaches of great interest in current times which has become a revolution in computer vision. Another widely used approach of object detection is HOG where matching of extracted features is carried out.

Over the past few years, researchers have come up with new and widely used techniques for identifying and tracking objects. Among them, general Template Matching and HOG are widely used techniques. This study focuses on the correct detection of desired objects using template-based methods. This paper uses HOG technique to find the desired object from a testing cluster image using a patch of a template image. We apply HOG based object detection method on images, observe the results and find the advantages and limitations of the technique. We also overview a comparison results of simple Template Matching and HOG based object detection method.

The rest of this paper is embodied as follows. Section II represents the related works of object detection techniques. Section III describes the small description of the methods named HOG feature and Template Matching. This chapter also includes the methods' flow diagrams and the corresponding algorithms for the methods. Experimental results and analysis of the performance based on some criteria are included in Section IV. Section V presents concluding remarks about the research.

II. Literature Review

Al-Mamun and Yousef investigated different types of methods for the segmentation of images and useful feature extraction from the images. They also proposed a model for the identification of flexible desired objects from an image with asymmetrical shapes [4]. Two feature detection techniques like Scale Invariant Feature Transform (SIFT) and Speeded UP Robust Features (SURF) were used for image registration [5, 6]. SIFT could detect more number of features but its' speed was not remarkable. But SURF showed better results in the case of both speed as well as performance [5]. A variant of a conventional HOG feature named Edge-HOG was proposed by Ren and Li to detect pedestrian and car [7]. Experimental results indicated that Edge-HOG was two times faster in speed compared to the conventional HOG. Chetan in [8] adjoined two external features like the shape and color of the object to detect an object swiftly and with a comparatively accurate detection rate. The results of the paper pointed out that the performance of the proposed method was comparable to other methods. In paper [9], researchers compared four widely used feature detection techniques namely SURF, Harris, FAST (Features from Accelerated Segment) and FREAK (Fast Retina Keypoint) in terms of accuracy and run time. The paper concluded that FREAK algorithm outperformed the other algorithms based on detection accuracy and time complexity. Multiple same instances were detected from a single template image using a new approach which was based on SIFT method but the scale and rotation invariant method named SURF was also used to extract the rotation and scaling of the features [10]. A method was proposed in [11] to detect moving objects from a video. In that paper background subtraction was used for object detection and two methods namely thresholding and edge detection were used for segmentation. Based on Peak Signal to Noise Ratio (PSNR) value, it was experimented that background subtraction showed better performance compared to thresholding. In [12], Nazil Perveen described various types of template matching techniques and emphasized on the applications of those techniques. Haar Cascade Classifier was used to identify human head by considering head image as an object in [13].

Most of the above papers used a feature-based object detection technique to detect a specific type of object like human, car, weapon, etc. This paper offers generalized techniques to identify the desired object from a source image. Again, none of the above researchers compared the prominent approaches, such as simple Template Matching and HOG feature-based method to compare the performance of these techniques in object detection. The paper includes a comparative discussion of HOG and Template Matching to present the drawbacks and advantages of these techniques.

III. Methodology

A. HOG Feature-based Method

HOG is a feature descriptor based approach that focuses on the extraction of features. In the feature descriptor of an image, only useful information is extracted and unnecessary information is thrown out. In HOG method the whole image is partitioned into small blocks and then the feature descriptor is completed for each block [14]. After extracting the useful features of each block of the image, those blocks are grouped together and then normalized to obtain contrast normalized features.

HOG feature extraction process: First, convert color images to grayscale. This process minimizes the color information. Next, calculate the value of each pixel's luminance gradient. Then, generate a gradient orientation histogram for each block. This process can get the feature quantity that is powerful in changing the form. Finally, the normalize value of the features is obtained for each block.

The stages of HOG feature extraction and overview of HOG method are depicted in Fig. 1 and Fig. 2, respectively.

Gradient image for a HOG descriptor can be represented in several color models like RGB (Red, Green, Blue), LAB (Color representation where L denotes lightness and A, B represent the color-opponent dimensions) and gamma. As most of the cameras would be RGB cameras, we can consider the input image to be RGB image which can be later converted into a gray scale image for processing.

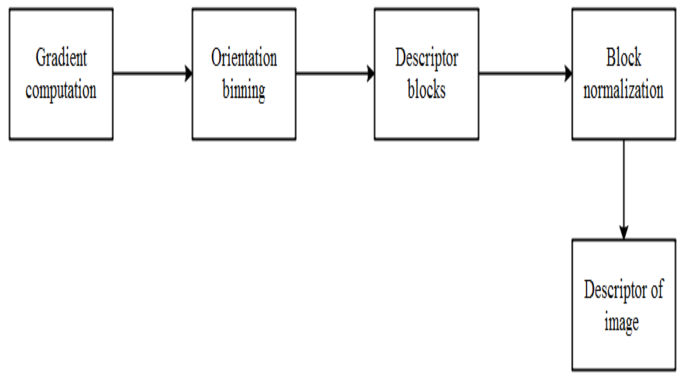


Fig. 1. Implementation of HOG Feature Extraction.

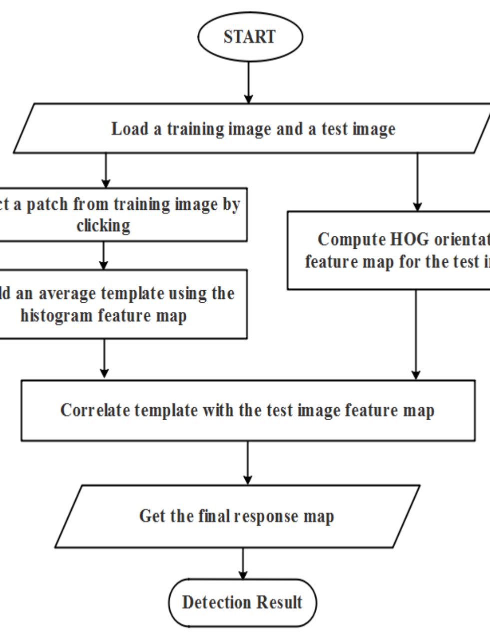


Fig. 2. Overview of HOG based Method.

B. Simple Template Matching Method

Template matching is a popular computer vision based image processing technique used to find out desired object from an input image. This method uses an image patch according to a specific feature of the search image, which we need to identify.The template matching uses a matching criterion to determine the position of an object and calculates a correlation coefficient. Template matching measures the similarity between the template image and the overlapped portion of the original image [15]. This similarity measurement is known as cross correlation. The cross correlation value will be greatest at locations where the input image matches the template patch or mask image [16].

Fig. 3 shows the flow diagram of Template Matching method.

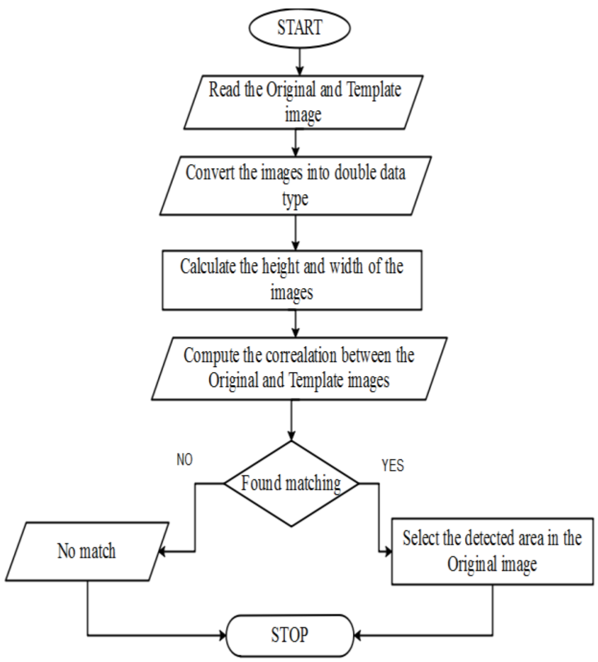


Fig. 3. Flow Diagram of Simple Template Maching.

IV. Experimental Results

A. Experimental Tool

The experiment is performed in MATLAB environment with a number of images.

B. Object Detection using HOG based Method

The experiment is applied to a large number of colored and grayscale images. Here, the paper presents experimental results for some images only. The main motivation of this experiment is to identify the correct location of the template object from the desired test image. For object detection from an image, we have used a template image. For result illustration, we have only used total six template images shown in Fig. 4. A patch (a group of pixels) is taken from a template for detection purpose. The program is run by changing the size of the template patch (128×128, 64×64, 32×32, etc.) and the results for the variants of patch size are observed. We also use the full template image but we do not get the desirable results.

For the detection of objects from a test image, template images have been used. Fig. 4(a), (b), (c), (d), (e) and (f) represent the template images for car, key, elephant, medicine box, staple remover and book, respectively. Fig. 5(a), (b), (c), (d), (e) and (f) show the detection results for the template images of Fig. 4(a), (b), (c), (d), (e) and (f), respectively. It is seen that car, key, elephant and medicine box are detected correctly but staple remover and book objects are detected incorrectly.

The result of detection using HOG features:

True Positive= 4 (Correctly finding the location of the desired objects)

False Positive=2 (Incorrectly detection of template objects)

From Table I, it is observed that 128×128 size of the patch for all the template images is suitable for the correct detection of objects. The size of the template patch 128×128 is divided into 16×16 blocks where each block is of 8 pixels. From this experiment, it can be said that the suitable patch size depends on the original size of the template and the patch size must be smaller than template size to detect the objects accurately.

C. Object Detection using Template Matching Method

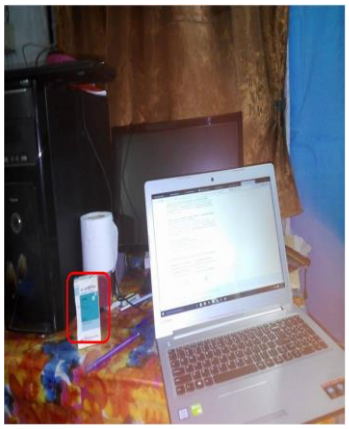
In the template matching method, this paper uses the cropped image of objects as a template image. Template matching cannot detect objects when we take the arbitrary size of the template image. Template of arbitrary sizes (e.g. 32×32, 64×64 and 128×128 etc.) are applied but it is observed that the investigated Template Matching system is unable to detect the image. In Fig. 6 we use the original template image and observe that the object is not detected. But in Fig. 7, all the objects are detected correctly.

Fig. 4. Sample of Template Images.

(a) car detected

(b) key detected

(c) elephant detected



(d) medicine box detected

(e) staple remover wrongly detected

(f) book wrongly detected

Fig. 5. Object Detection Rsults using HOG Method.

TABLE I. THE DETECTION RESULT OF HOG FOR DIFFERENT SIZES OF THE PATCH OF THE TEMPLATE IMAGE

Patch Size / **Template**	**256x256**	**128x128**	**64x64**	**32x32**	**16x16**	**8x8**
Car (225x300)	No	Yes	Yes	Yes	No	No
Key (231x149)	No	Yes	No	No	No	No
Elephant (389x375)	No	Yes	Yes	No	No	No
Medicine box (385x505)	No	Yes	Yes	No	No	No
Staple remover (385x504)	No	No	No	No	No	No
Book (640x480)	No	No	No	No	No	No

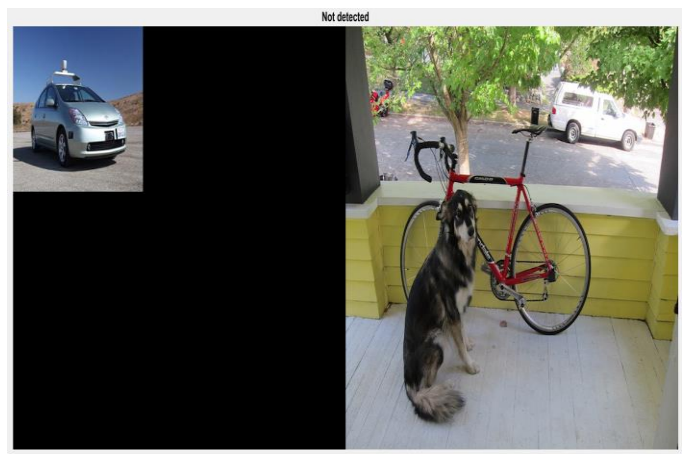


Fig. 6. Object Detection Results using Template Matching Method.

(a) car detected (b) key detected

(c) elephant detected (d) medicine box detected

(e) staple remover detected (f) book detected

Fig. 7. Object Detection Results of Template Matching using Cropped Template Images.

TABLE II. ELAPSED TIME FOR DETECTION

Template Image	Elapsed time for HOG (in second)	Elapsed time for Template Matching (in second)
Car	0.731388	8.449037
Key	0.680365	5.035367
Elephant	1.146820	8.031569
Medicine box	1.035807	8.09263
Staple Remover	0.974079	8.55565
Book	0.916373	4.727828

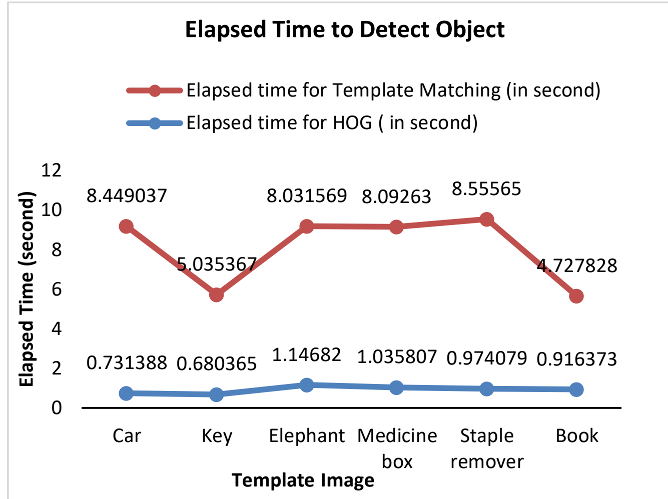


Fig. 8. Detection Time for HOG and Template Matching Methods.

Table II shows the elapsed time in second for the investigated techniques.

From Fig. 8, it is seen ghaphically that in the detection of the image, template matching elapses more time than the elapsing time of HOG method for each of the object class.

V. Conclusion

The paper addresses the issue of the detection of the desired objects from a test image using two methods named HOG feature-based method and template matching method. In this paper, the performance of these methods has been analyzed using several images. The research is tested on a sample of six images from the database of 20 images for different types of objects. Template Matching uses simply pixel-based cross-correlation matches which is easy to implement. It only works well when the template image is cropped from the original image otherwise it shows poor results in object detection. HOG method uses feature descriptors to detect images. In this method, the cross-correlation between the template and feature descriptor is used. It requires less time to run the detection process.

Now, it is concluded that the implementation of HOG based method is comparatively complex but it shows optimum results based on both detection accuracy and elapsed time.

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A Compact Broadband and High Gain Tapered Slot Antenna with Stripline Feeding Network for H, X, Ku and K Band Applications

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Abstract*—In this paper, a planar travelling wave tapered slot antenna with compact size is proposed for wireless communication applications. The prototype of antenna is developed on Roger RT/Duroid 5880 laminate with tan δ = 0.0009, a relative permittivity of 2.2 while working in the range of 6GHz – 21GHz. The simple feeding technique transits with radial cavity and the opening taper profile. The antenna dimensions of the antenna have been designed in such a manner so as to enable impedance matching. The parametric study of the variables is carried out by various scrupulous simulations. The designed characteristic antenna has achieved an impedance bandwidth in the broadband spectrum of 111.11% at the minimum 10-dB return loss and peak realized gain of 7dBi is obtained for a resonant frequency of 19.6GHz. The simulated results are in good agreement with experimental results and hence make the antenna suitable for H (6 - 8 GHz), X (8 - 12 GHz), Ku (12 - 18 GHz) and K (18 - 26 GHz) and future wireless communication applications.

***Keywords*—Tapered slot antenna (TSA); compact; radial cavity; broadband impedance bandwidth; peak realized gain; etched slots**

I. Introduction

Wireless communication is rapidly growing the demand of smart antennas for the users to provide the more information on a rapid rate. Broadband and high gain antennas are essential components in enabling wireless connectivity. Various wideband communication antenna devices require different features such as low profile, linear polarization, compact dimensions and the unidirectional radiation pattern [1]. A tapered slot antenna (TSA) is one of the types of travelling wave antennas or planar end-fire antennas which have received considerable attention due to their wide impedance bandwidth characteristics. Vivaldi antennas have been used in numerous applications like satellite communications [2], Ultra-wideband (UWB) [3-4], scanning phased array [5-6], vehicular communication system [7], imaging construction material [8], medical imaging [9-10], cognitive radio [11], brain tumors [12], and GPR system [13-14]. The end-fire travelling wave antennas have demonstrated broadband bandwidth, high gain and symmetrically E – H beam pattern. TSA possessed many advantages of compact size, low profile, compatibility with microwave integration circuits, planar structure and ease of fabrication process [15]. The tapered slot antenna consists of a feedline, which is usually stripline or microstrip line transition and the radiating structure are constructed by linearly, exponentially and elliptically curves. All these properties particularly have the larger physical and electrical dimensions, narrower impedance bandwidth and moderate gain i.e. the major concern for the antenna researchers. Improving the main parameters of the proposed antennas like gain and stable radiation pattern as well as impedance bandwidth for the H, X, Ku and K band applications has been the focus of antenna designers [16]. In satellite communications, the microwave prescribed frequency bands allocated by IEEE standard for radio waves and radar communication with frequency which range from 6GHz-8GHz, 8GHz-12GHz, 12GHz-18GHz and 18-26GHz, respectively.

Last few years, the researchers have published numerous reports on the different shapes of antennas with compact dimensions to improve the bandwidth, gain and radiation pattern with analysis of alternative techniques and the optimization of the antenna parameters in the approved spectrum. In the literature, some antennas have large dimensions, preventing their use in miniaturized applications. In [17], Zhang et al. presented the small size microstripline-fed LTSA (Linear Tapered Slot Antenna) with the design of tilt grooves. The proposed antenna designed on Teflon substrate with the compact dimensions of $16\times21\times0.6$ mm^3 to improve the wide bandwidth and beamwidth of LTSA antenna. But with larger electrical size and complex structure. Besides, a broadband TSA for Microwave imaging applications with the size of $48\times36\times0.762$ mm^3 have been proposed in [18]. The presented antenna has been covered 8-18GHz bandwidth with the larger antenna size. In [19], Tseng demonstrated the linear tapered slot antenna (LTSA) for UWB radar sensor applications with the antenna dimension of $110.2\times31.5\times0.762$ mm^3. Furthermore, a broadband microstrip

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antenna for C, X and Ku band applications with physical size of 21×15×31.75 mm^3 have been outlined in [20]. The exhibited antenna structure consists of semi-triangular patch shape with a coplanar waveguide feedline. The proposed antenna has achieved 107% fractal bandwidth and 5.3dBi gain. The new shape of wideband antennas were presented in [21-22]. However, the employed techniques have achieved the broad impedance bandwidth with larger dimensions. Furthermore [23], provides an antenna design with a tapered slot to be used in microwave band communication underwater. The proposed antenna achieved the above 57% bandwidth with electrical size 90×69×1.2 mm^3. We propose the antenna for H, X, Ku and K band applications with compact physical size.

In this paper, we present the compact high gain antenna with a tapered slot that operates in the broadband spectrum and can be used for the satellite communications, radar system, weather monitoring and very small aperture terminal (VSAT), etc. applications. The proposed antenna dimensions are (18.9×13.2×0.508) mm^3 and the broadband impedance bandwidth of 111.11% at the 10-dB return loss has been achieved. Finally, the proposed antenna design provides maximum gain, stable radiation pattern and strong current distribution along the direction of opening tapered aperture.

The organization of the paper is categorized mainly in four sections. Section II covers antenna layout and design strategy. The effect of antenna performance parameters and simulated results and discussion are analyzed in Section III, and finally Section IV gives the conclusion.

II. Antenna Design Layout

Fig. 1(a) depicts the antenna design structure. The design of TSA antenna is performed simple these steps:

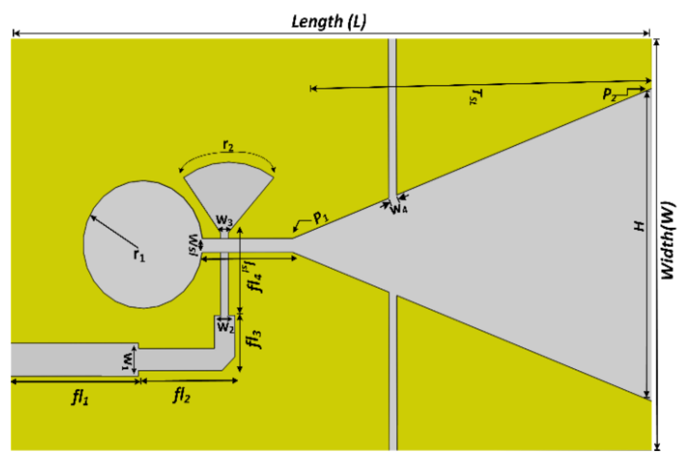
- It consists of dielectric substrate, ground plane and cavity stub used with slot and tapered lines.
- The feedline is constructed with radial stub balun and the matching transformer which is put a top the substrate.
- The performance of antenna mainly depends on the aperture width (H). Generally, it should be greater than $\lambda_0/2$.
- A coaxial-fed tapered antenna cannot provide wideband impedance bandwidth which is needed in many broadband antenna applications. Hence alternative feed network such as several types of baluns, stripline to slotline or microstrip line to slotlines is used.

The top of the substrate is engraved with the tapered profile with compact dimensions (18.9×13.2×0.508) mm^3. The wavelength of antenna is used the minimum frequency of interested band. The dielectric substrate RT/Duroid 5880 laminate is used with a value of 2.2 for its relative permittivity, loss tan $\delta = 0.0009$ and the standard thickness of 0.508mm. The linear tapered slot can be classified two sections, antenna design parameters and the substrate. The antenna design elements can be categorized into the opening tapered rate, circular cavity, the slotline and stripline transition connected with balun.

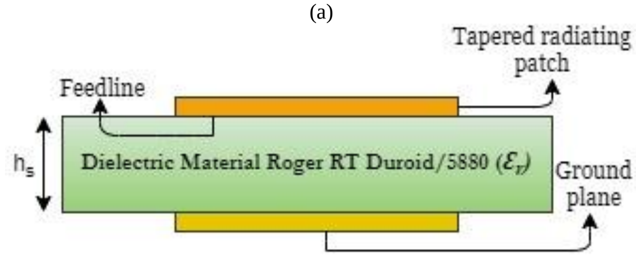
Furthermore, the slotline or stripline transition is specified by the stripline (w_1, w_2 and w_3) and the slotline (W_{sl} and W_4) width. The width of W_4 is usually cut for the proper broadband impedance matching. The linearly tapered profile can be parameterized R (the opening rate) and the two tapered points P_1 (x_1, y_1) and P_2 (x_2, y_2). P_1 and P_2 which are the starting and ending points of the opening tapered profile. The proposed antenna structure provides a suitable radiation pattern and the wide impedance bandwidth from the 6 GHz – 21 GHz.

The tapered T_{sl} is (x_2 - x_1) and aperture height H is $2(y_2 - y_1) + w_{sl}$. For the case where R tends to zero, the taper layer results in a LTSA with a slope given as $s_0 = (y_2 - y_1)/(x_2 - x_1)$. In the case of an exponential taper slope, s will change from its initial value of s_1 to s_2 where these values are taper slopes for $x = x_1$ and $x = x_2$ respectively and $s_1 < s < s_2$ for $R > 0$. Moreover, $\alpha = \tan^{-1}s$ is the flare angle for the taper. Furthermore, the parameters which define the flare angle, H, T_{sl}, R and w_{sl} are interrelated. Fig. 1(a) also shows the parameters relating to the circular slotline cavity and stripline feeding. The below figures depict the top and side view geometry of the tapered slot antenna. However, the below section deliberates on the impedance matching, parametric studies and feedline transition of the proposed antenna structure. Fig. 1(a & b) also illustrate the dimensions of the Duroid substrate and patch remains same.

The designed antenna is simulated by using the EM solver High frequency structure simulator (HFSS). Table I lists the optimized values of the parameters.



(a)



(b)

Fig. 1. (a & b) Top and Side view Geometry of the Proposed Antenna.

TABLE I. GEOMETRIC DEFINED VARIABLES OF PROPOSED ANTENNA (UNIT: MM)

Variable name	***Optim.Value***	***Variable name***	***Optim.Value***
W	13.2	l_{sl}	2.85
L	18.9	W_{sl}	0.55
h_s	0.508	W_1	1.6
H	11.4	W_2	0.7
r_1	1.55	W_3	0.4
r_2 (theta)	100 deg	W_4	0.3
phi	50 deg	$f_{l.P}$	0.25
T_{sl}	10.925		

III. SIMULATED RESULTS AND ANALYSIS OF THE PROPOSED ANTENNA

This section details the impedance matching of the designed antenna in relation to the defined variables.

Furthermore, the results of the peak realized gain (dBi), radiation pattern, return loss (S_{11}) and surface electric current (J_{surf}) distribution are also discussed and analyzed.

A. Parametric Study of the LTSA Antenna

The section discusses the effect of feeding line width (w), feedline position (f_{lp}), the effect of radius (r) and the width of slot (w_{sl}). These parameters realize the running the multiple times accurate simulations which effects the matching behavior of proposed antenna. Lastly, the best values are used to test the suggested antenna design.

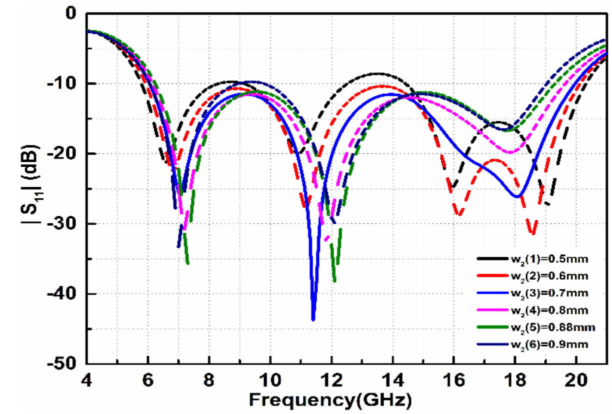
1) Variation in feedline widths (w_1,w_2 & w_3): The width of the feeding lines is the essential parameter in the proposed antenna. Initially, the values of feedline width are chosen according to the antennas frequency of operation which is near to the 1.55mm at the 50Ω of the feedline and then optimized the variable with iterative methods. The proposed antenna can be excited by microstrip feed via slot line transition and radial stub for best impedance matching performance. Fig. 2(a)-(b) and (c) illustrates the wideband performance in 6GHz to 21GHz frequency range.

Fig. 2(a) illustrates the various optimetric values used for feedline width (w_1) ranges from 1.3mm to 2.0mm. It is observed that the suggested antenna attains the proper matching at 1.6mm which can clearly appear in solid line.

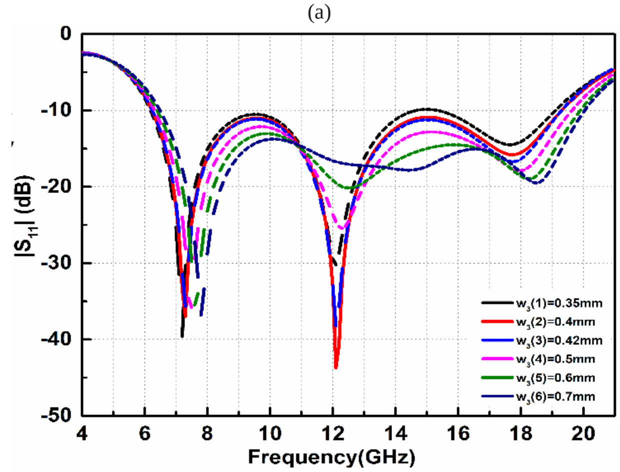
Applying the variation in the feedline width of (w_2) ranges from 0.5mm to 0.9mm and (w_3) varies from 0.35mm to 0.7mm, the optimum results have been achieved at the 0.7mm (blue color) and 0.4mm (red color), the initially calculated values were 0.88mm and 0.42mm at the operable frequency.

2) Variation in feedline position (f_{lp}): The performance of the antenna feedline position is analyzed to improve impedance matching characteristics. The tapered antenna radiator can be excited with feedline. Fig. 3 illustrates the variation of the feedline position from -0.25mm to 0.25mm. The optimized feeding position has been achieved at -0.25mm. Moreover, the dimensions of feedline transition also influence the antenna impedance. It is analyzed to set proper dimensions of the feedline length and width to achieve broad bandwidth performance and impedance matching.

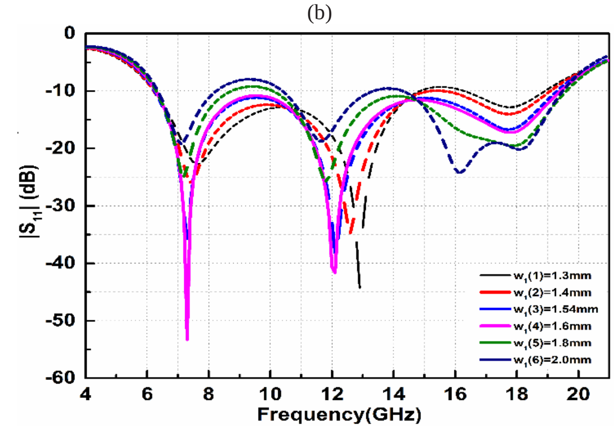
3) Effect of radial cavity (r) and slotline width (W_{sl}): The effect of TSA radial stub and slot line width on performance are analyzed by varying antenna dimensions such as width, length and stripline. TSA antenna radius cavity is connected to the slotline and tapered section which represent the fixed monopole radiation characteristics of an antenna. Fig. 4(a) gives the results of radial stub variation against frequency. The optimum results are achieved at 1.55mm.



(a)



(b)



(c)

Fig. 2. (a, b & c) Return Loss (S_{11}) Performance of Feedline widths (w_1,w_2 & w_3) Against Operable Frequency Range.

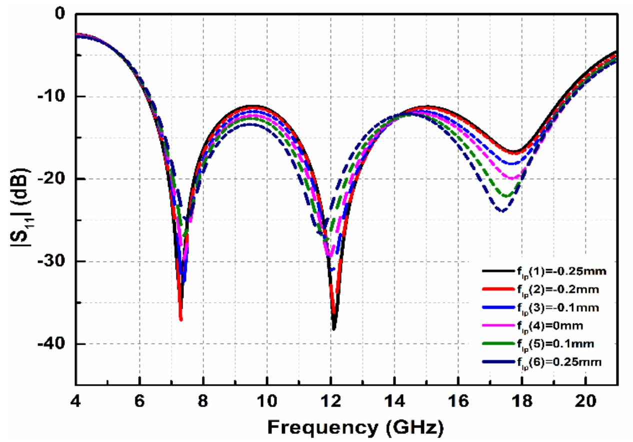


Fig. 3. Variation of Return Loss (S_{11}) with Frequency for different Values of Feedline Position (f_{lp}) of Proposed Antenna.

The width of slotline (w_{sl}) transition is varied with different optimetries values ranging from 0.35mm to 0.7mm. It can be observed from Fig. 4(b) that the best result for impedance matching is achieved at the value of 0.55mm.

Initially, we design the proposed antenna without cutting the slot on top of substrate. The simulated results cover the BW from 9.87GHz to 21GHz. The slotline is etched at the top of the tapered patch, the simulated return loss covers the broad impedance bandwidth of 111.11% as illustrated in the Fig. 5.

The multiple optimetric variations of the slotline width further enhances the impedance characteristics of the tapered antenna. The slotline is cut on the top of tapered profile, the antenna covers the (6GHz – 8GHz) broad impedance bandwidth with the optimetric slotline width (w_4) at 0.3mm. The length of slot cavity section and tapered rate covers the high frequency resonance.

B. Simulated Results and Discussion

1) Return Loss (S_{11}) and Peak Realized Gain (dBi): The simulated analysis of return loss and the gain is presented in this section. Fig. 5 depicts the return loss for all frequency sweeps performed in the experiment. The simulated analysis of return loss (S_{11}) has been generated by using the Ansys high frequency structural simulator (HFSS).

It can be seen from the results, that the relative impedance bandwidth has been achieved 111.11% at minimum return loss i.e. 10-dB with multiple resonant frequencies of 7GHz, 11.8GHz, 15.8GHz and 19.6GHz. The geometrical parameter of theta (r_2) and phi have been affected on the impedance matching which have considered 50^0 and 100^0. The proposed antenna is analyzed that lower and upper frequency range from 6GHz to 21GHz at 15GHz broadband impedance BW. It covers the H, X, Ku and K band applications.

The value of VSWR for this antenna are declining at the multiple resonances 1.09 @7GHz, 1.01 @11.8GHz, 1.02 @15.8GHz and 1.2 @19.6GHz at the desired operable frequency which are remains < 2.

From Fig. 6 plots peak realized gain achieved for the proposed antenna. For each of the multiple resonant frequencies, at 7GHz the antenna shows a gain of 3.42dBi, at 11.8GHz the acceptable gain of 3.24dBi, at 15.8GHz the noted gain of 6.40dBi and the 19.6GHz the gain of approximately 7dBi is achieved. Moreover, the maximum peak realized gain of 7.38dBi has been obtained at 17.5GHz. The suggested antenna achieved the peak realized gain of multiple bands for wireless communication applications.

2) Radiation pattern: Fig. 7 illustrates the far-field radiation pattern in 2D for the antenna along standard planes (E-plane and H-plane) with Fig. 7(a) – (d) showing the antenna radiation pattern for the multiple resonant frequency case. It can be seen that the travelling wave antenna exhibits a stable radiation pattern at multiple resonance frequencies. The antenna beam directs itself towards the 0-degree direction as required while radiating equally in the other plane too.

The antennas surface current distribution (J_{surf}) is shown in Fig. 8. The feed line and radial cavity with slot line show a high intensity of current levels at the various resonant frequencies.

The surface current is distributed across the tapered section which represent the stable characteristics of the radiation pattern in 3D view.

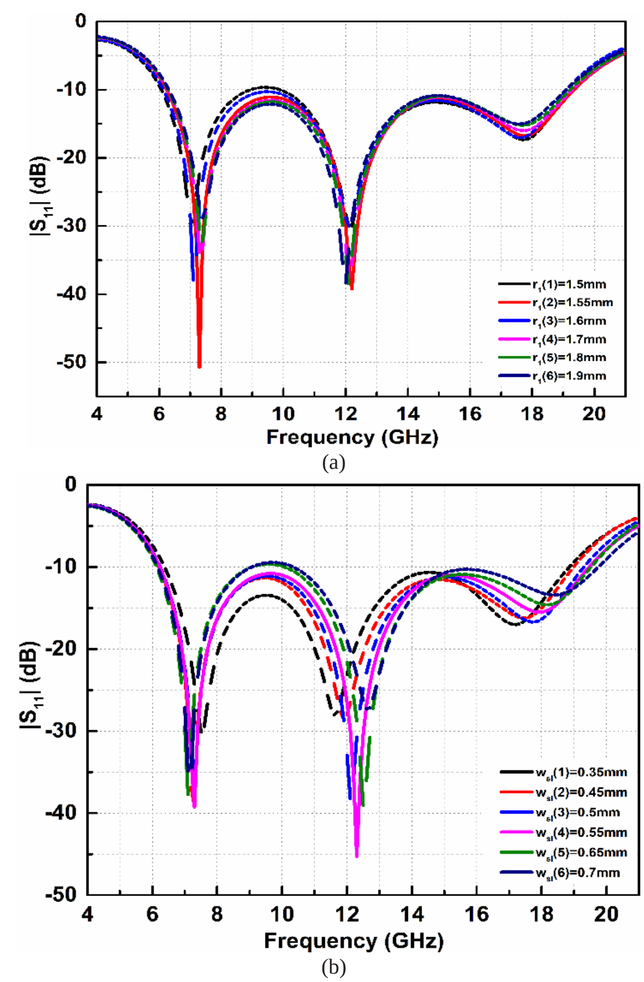


Fig. 4. (a & b) Impedance Matching Analysis Related to Radial Cavity (r) and width of Slotline (w_{sl}) with different Values of the Proposed Antenna.

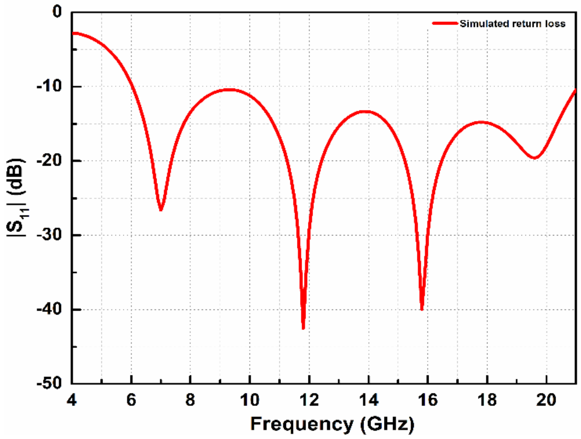


Fig. 5. Response of Return Loss Against Frequency.

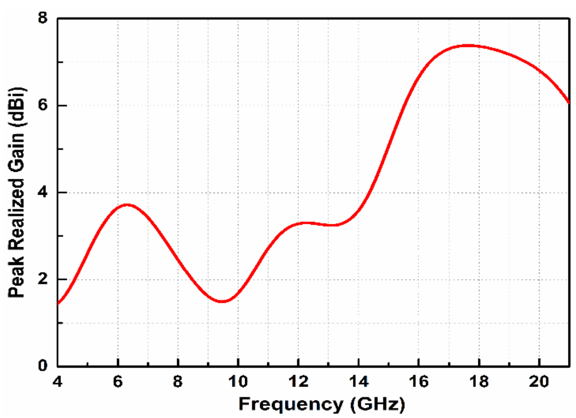


Fig. 6. Simulated Peak Realized Gain Across the Operating Frequency Span.

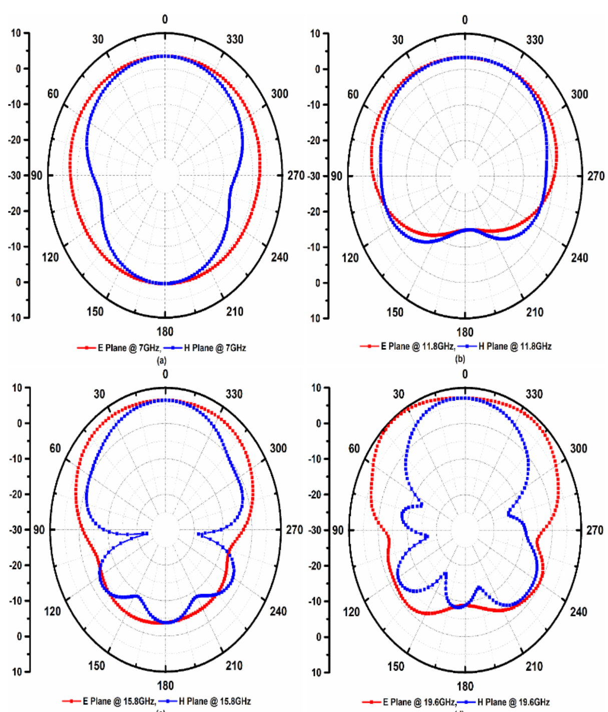


Fig. 7. Radiation Pattern at Azimuth and Elevation Plane of the Proposed Antenna at Multiple Resonances; (a) 7GHz at $\theta=0^0$ and $\theta=90^0$. (b) 11.8GHz at $\theta=0^0$ and $\theta=90^0$(c) 15.8GHz at $\theta=0^0$ and $\theta=90^0$(b) 19.6GHz at $\theta=0^0$ and $\theta=90^0$.

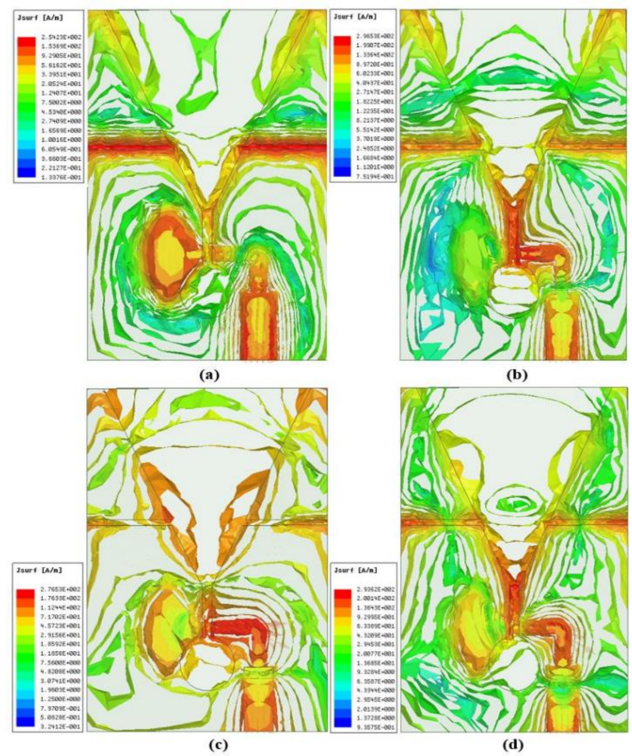


Fig. 8. Simulated Surface Electric Current Distribution Sketches (a) Resonance @7GHz, (b) Resonance@11.8 GHz, (c) Resonance @15.8 GHz and (d) Resonance @19.6 GHz.

IV. Conclusion

The travelling wave tapered slot antenna for H, X, Ku and K band application towards wireless communication has been studied and proposed. The proposed antenna structure contains of the dielectric substrate, opening taper profile, feeding network and ground plane. The broadband impedance matching of designed antenna has been attained by setting up the proper dimensions of feedline transition and the slot cut on both sides at opening taper of antenna. The antenna has been shown to provide impedance bandwidth of 111.11% and high gain of 7-dBi at K-band frequencies, substantial gain of 6.40-dBi at Ku-band, gain of 3.24-dBi at X-band and the acceptable gain of 3.42-dBi for H-band wireless communication. The tapered slot antenna has been designed and simulated by HFSS 17.1. Moreover, this antenna will be further extended by suing the efficient Wilkinson power divider and then its performance will be studied in a real time environment for further exploration.

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QUES: A Quality Estimation System of Arabic to English Translation

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***Abstract*—Estimating translation quality is a problem of growing importance as it has many potential applications. The quality of translation from Arabic to English is especially difficult to evaluate due to the languages being distant languages: different in syntax and low in lexical similarity. We propose a feature-based framework for estimating the quality of Arabic to English translations at the sentence level. The proposed method works without reference translations, considers both fluency and adequacy of translations, and does not imply assumptions on the source of translation (humans, machines, or post-edited machine translations); thus, making the solution applicable to increasingly more situations. This research solves the translation quality estimation problem by treating it as a supervised machine learning problem. The proposed model utilizes regression algorithms (SVR and Linear Regression) to predict quality scores of unseen translated texts at runtime. This is accomplished by training models on a labeled parallel corpus and mapping extracted features to the quality label. The prediction models succeeded in predicting fluency and adequacy of translations with a Mean Absolute Error of 0.84 and 1.02, respectively. Furthermore, we show that in a similar setting of our approach, fluency of an Arabic to English translated sentence on its own, is an appropriate indication of a translation's overall quality.**

***Keywords*—Translation quality estimation; translation adequacy; translation fluency; supervised machine learning**

I. Introduction

A good quality translation plays an important role in transferring knowledge and it has great impact on the global economy by allowing businesses to grow globally without the inconveniences of language barriers. In addition, it informs the end-users about the reliability of a translated content and helps in determining if a translated text is ready to be published or if it needs further editing.

Hence, the ability to assess the quality of a translation is critical in order to guarantee its effectiveness in information delivery. The task of assessing the quality of translated content and its appropriateness for use or publishing is usually performed by experts in translation. It is also done automatically using machine translation evaluation systems. The former approach can be very expensive and time-consuming, while the latter requires reference translations in order to perform a comparison operation and evaluate the translation quality. A reference translation is a manually developed translation by an expert translator that is essential in automatic translation evaluation. Automatic evaluation is done by different measures of comparison between the produced translation and the reference translation [14]. Reference translations are expensive and require manual labor and time to produce, thus this approach is also proved costly.

Translation Quality in this research is defined as a function of translation fluency and translation adequacy. As defined in [38], fluency indicates "how well the produced translation is grammatically fluent and natural in the target language" while adequacy indicates "the semantic equivalence between a source sentence and its target translation". In other words, adequacy demonstrates how well the produced translation conveys the same meaning as the original text.

The lack of automated tools that estimate the quality of Arabic to English translation has been the main motivation behind this research. By using such a tool, it will be possible to assess the quality of Arabic translated content and it would be possible to make suitable remedial actions to the translated content accordingly.

This research aims to develop a translation Quality Estimation model (QUES) for Arabic to English translations that requires no access to a reference translation or the source that performed the translation. In addition, this research aims to suggest a measure of the adequacy and fluency of a translation from Arabic to English translations. The goal is to inform an end-user about the reliability of a given translation from Arabic to English at the sentence level.

This paper is organized as follows: In Section II, an overview of translation quality is discussed and is followed by a discussion on translation quality of machine translations in Section III. Human translations are briefly discussed in Section IV. Section V presents the Quality Estimation (QE) of translations without a reference and the QE granularity levels. Related work is discussed in Section VI. The dataset, feature sets, experimentation, and results of our model are discussed in Sections VII, VIII, and IX, respectively. Finally, the conclusions of this paper and future work are discussed in Sections X and XI, respectively.

II. Translation Quality

Translation is the process of replacing or converting a source text (ST) that is written in a source language (SL) into target text (TT) in a target language (TL) [22, 32]. To call a translation an equivalent translation, the TT must be functionally equivalent to the ST [12, 22], which describes a semantically and pragmatically equivalent texts and holds whenever a TT have the same communicative effect as the ST.

Furthermore, a translation can either be literary oriented or linguistically oriented. The literary oriented approach is used to translate literary texts. This is done by manipulating the TT to fit the literary and cultural context of the TL, without giving much emphasis on the relationship between the ST and the TT. Whereas the linguistically oriented approach gives significant emphasis on the relationship between the ST and the TT by considering the functional equivalence [22].

How to determine whether a translation is good or bad is one of the intriguing questions that is connected with any translation. Researchers agree that there is no unified method to measure the quality of a translation [11, 15]. However, long-standing studies and models with different evaluation measurements have been developed over recent decades. In [42], the author states three concepts involved in most of the established models and criteria of Translation Quality Assessment (TQA). The first concept is the quality of the producer (human or machine). The second one is the quality of the process, which includes how the process was predefined, and whether it was followed in order to obtain a good translation. The last one is the quality of the product that includes predefined evaluation standards. Nonetheless, current models aim at focusing on the quality of the product [3].

A plethora of TQA approaches has been developed over the years. Some researchers follow a non-linguistic approach where the features and relations between the original text and the translated text are not considered but rather the focus is on the translation's psychological or behavioral effects on the receivers of the translated text [21]. Linguistic approaches, on the other hand, compare both ST and TT according to various criteria such as coherence, semantics, and syntax. However, these criteria might differ based on the evaluation process. Most of the recent works are taking linguistics-oriented approaches into account [21]. In [3], the author states two main approaches that promise to provide an objective assessment of translation quality: error-based approach and holistic approach. Error-based approaches aim to measure only the errors or defects in a translation. The holistic approach which was first proposed by [43], considers both negative and positive aspects of the translation. Holistic models can be classified into two categories [27]: equivalence-based and nonequivalence-based approaches. In equivalent-based approaches, similarities between the ST and TT are tested and evaluated such as linguistic and narrative structures, overall textual volume and layout, coherence of thematic structures, lexical properties, and grammatical\syntactic equivalence [33].

On the other hand, non-equivalence-based approaches focus on different concepts such as text function and purpose. In [8], the author proposed a model that used assessment parameters or evaluation standards, which were adapted from different linguistic scholars such as [20, 45]. These parameters are as follows: a) the sufficiency and adequacy of the translation based on a semantic and formal language level, b) purpose: whether the translated text is appropriate for the intended purpose, c) context: considering factors such as the target audience, the time and place in which the translation is used, and the text type, and d) language norm: the fluency of the translation such as syntax, grammatical mistakes, spelling mistakes, and punctuation mistakes.

III. Machine Translation Quality

Machine translation (MT) refers to fully automated machines that translate a source text in a natural language into a target text in another natural language. There are three different approaches to machine translations: a) Rule-based approach [17], Statistical MT (SMT) [7], and Neural MT [44].

The central idea behind MT evaluation is assessing the degree of proximity of a translated text to a human translated text. Many methods to evaluate MT were proposed. The most three common methods to evaluate MT performance are discussed here.

The Round Trip Translation Assessment is performed by taking the translated TT and translating it again using the MT system to produce what is called the backward translation, and evaluating the MT system based on how close the backward translation is to the ST [13].

Human evaluations of the MT systems are conducted manually by translation experts. The adequacy and fluency measures are scored through various scales: (1-5), (1-7) or even (1-9) [28]. Although human evaluations of machine translation are expensive, they are very expensive. Therefore the field of automated MT evaluation emerged.

Automated evaluation systems are based on the measure of similarity between a text and a reference human translated text [35]. The most used evaluation measures are BLEU [35], NIST [14], METEOR [4], and TER [34]. For example, BLEU measuring rubric use a weighted average of variable length phrase matches against the reference translations by comparing the n-grams of both the translation and its reference translation[35]. The range of BLEU scores range between 0 and 1 where scores greater than 0.30 means that the translation is understandable while scores greater than 0.50 reflect much better fluent translations [1].

In summary, most current MT evaluation metrics are based on comparisons between machine translations and human references and are based on evaluating the lexical similarity at the n-gram level. There are two challenges for the automatic MT evaluation methods [30]: a) the use of reference translations which are costly from an economic perspective, and b) the focus on fluency of the output text which lacks the integration of semantic information in MT. This has led to MT systems that are illiterate in terms of semantics and meaning [30]. To solve these problems, the authors in [38] proposed to perceive the MT evaluation problem as an adequacy estimation problem and replace the use of reference translation by quality indicators for unseen translated sentences.

IV. Human Translation

Human Translation (HT) is the process of translating source text in one language into target text in another language which is performed by humans. The separation between HT and MT is increasingly indistinct nowadays due to the availability and widespread of Computer-Aided Tools and accordingly it is not possible to distinguish between a translated text produced by humans, machines, or post-edited machine translations [11]. Consequently, researchers argue that approaches and measures for evaluating translation quality could be unified [11]. Some work has been dedicated to investigating the correlation between MT and HT of the same source text. It has been found that there is a strong correlation in English-to-Spanish [10] and English-to-Arabic [2]. Hence, in this research, assumptions about the source of translation are omitted and a non-equivalence based approach is followed which can be applied to HT and MT at the same time.

V. Translation Quality Estimation

Translation Quality Estimation (QE) is an automatic evaluation framework that avoids the use of reference translations. It aims to provide a quality indicator for machine-translated sentences at various levels (word level, sentence level, document level) [38]. Translation quality estimation is generally addressed using Machine Learning (ML) techniques to predict quality scores [9, 23, 24, 46]. The most common method in these approaches is considering the problem as a supervised learning task using standard regression or classification algorithms to predict various quality labels. QE solves the challenges in MT evaluation by adapting cross-lingual semantic inference capabilities and judging a translation [30]and utilizing machine learning to infer the relationship between texts and their corresponding quality label from the training data. Attempting to extract features that represent the adequacy of a translation, rather than the fluency of the target text alone.

Adequacy in the context of translation is defined as "semantic equivalence between source sentence and target translation", in other words, an adequate translation is a translation that preserves the meaning of the input text and does not add any information to it [38]. Fluency, on the other hand: is the grammatical correctness of a target translation, in other words, a fluent translation, is said to be a grammatical and naturally occurring text in the target language. Mostly, both adequacy and fluency are the two most desirable features for a correct translation [30]. MT Evaluation metrics rely entirely on the fluency of the produced text (target text), which proved to be a weak point. In an effort for more robust quality estimation systems, the author in [38] proposed considering adequacy in estimating the quality of a translated text.

QE is done on various granularity levels, on the word level, the sentence level, or on the document level. Granularity-level refers to the type of portion of text the QE system is trained on and therefore is expected to evaluate. Sentence-level QE was the first form of QE [6], the QE system is trained on translated sentence pairs in order to evaluate sentence pairs at runtime. As for document-level QE, it consists of predicting the quality of text sizes larger than sentences: document at a time. For word-level QE, the system is trained and expected to run on individual words. The use of word-level QE is to highlight the specific words that need editing or to inform readers which parts of the sentences are not reliable, among other uses.

VI. Related Work

In this section, works related to the quality estimation problem are discussed. The approaches may vary in many aspects such as the source and target languages, the criteria for evaluation, the machine learning models, or the text granularity level.

A fair amount of research and progress in QE has been led by the shared task competitions proposed at WMT (the Workshop on Statistical Machine Translation) [6]. The WMT started in the year 2006, and every year, introduced different tasks centered on Statistical Machine Translation (SMT) topics that vary in purpose. Some of the tasks are translation tasks, challenging participants to produce SMT systems that produce results better than the baseline SMT system provided. Other tasks challenge participants to produce new MT evaluation metrics (like BLEU, TER, etc.). At the 6th round of WMT: WMT12, a new task was proposed (which is the interest of this research) motivated by the recent work in considering adequacy in translation quality prediction [38]. The task was named Quality Estimation, and it is regarded as the first emergence of QE as it is now known. The tasks started with estimating the quality of the translation produced by MT systems. Utilizing features describing how the MT system works, for example, its confidence levels in the translation and the language model used. But the task of QE evolved over time, after proving the ability to achieve great results needless of the details of the MT system that produced the translation [5]. The irrelevance of the source of the translation allows the QE framework to solve more general problems, thus allowing it to be more applicable in increasingly more situations. For example, the case where more than one MT produced a given text, or that the text was translated by humans.

TABLE I. Review of Relted Work

Reference	Language Pair	Source of translation	Granularity Level	Quality criteria	Features	ML	Metrics
[26]	English to Spanish	MT	Sentence	Post editing effort	Baseline-Latent Semantic Indexing	Support Vector Machine	HTER
[46]	English to Chinese	HT	Sentence	Fluency - Adequacy	Monolingual features, bilingual features, language modelling features, and bilingual embedding	Support Vector Machines- Relevance Vector machines	scale of 60 points
[24]	English to German	MT	Word\sentence\phrase	-	POS taggers	Predictor-Estimator Neural Model + stack propagation	BAD\OK
[23]	English to French\Spanish\Russian	Neural MT (NMT)	Sentence\document	-	Black box features + Baseline features from Quest++	Bi-directional Recurrent Neural network (bi-RNN)	HTER for sentence level & BLUE for document level

As mentioned in Section V, one common approach is to treat the problem as a supervised learning task. Recently, neural networks have been used to improve the performance of QE. A review of some recent works is listed in Table I.

VII. QUES SETUP

In the following subsections, the experimental setup of QUES is demonstrated in detail.

A. Dataset

It is very important for non-English universities to provide high quality translated web content in English to attract international students and scholars. In addition, educational web ranking institutions such as Webometrics and USNews are concerned with the English content on the websites of universities. The aforementioned issues have motivated the choice of the dataset domain of this work. In this work, we are interested in evaluating the quality of translations from Arabic to English in university web pages.

Part of the corpus is collected from the Open Parallel Corpus collection (OPUS) [22, 41]. The OPUS is a collection of translated text sentences from various resources that provide parallel corpora that are aligned and linguistically annotated. The Wikipedia Corpus is a collection of translations published by the Wikimedia Foundation and their article translation system [41]. In order to align the collected data with the domain of this research, the data was filtered by the educational domain. The filtering was performed automatically using keywords which indicate an educational content in the sentences, and hence only sentence pairs (corpus instances) including educational content are selected. In order to enrich the dataset, a second source of corpus was collected by volunteers from the King Abdulaziz University's E-portal website. The total number of sentence pairs in both data sets is 5571 instances.

In this work, both adequacy and fluency are the features used to estimate the quality of correct translations, and they both were used for labeling the data. In [38], researchers introduced adequacy in a 4-point scale (1-4) measure. However, this scale was complex for a learning model to distinguish between 3 & 4, and 2 & 3, which requires more complex features. Therefore, in this research, adequacy, and fluency are measured using a 5-point scale [25]. The definition of adequacy scale is defined as follow:

5. All Meaning expressed in the ST appears in the TT.
4. Most Meaning of the ST is expressed in the TT
3. Much Meaning of the ST is expressed in the TT
2. Little Meaning of the ST is expressed in the TT.
1. None of the meaning expressed in the ST is expressed in the TT.

While fluency scale is defined as follows:

5. Flawless English: no grammar errors, good word choice, and syntactic structure in the TT.
4. Good English: few terminology or grammar errors that do not impact the overall understanding of the meaning.
3. Non-native English: about half of the translation contains errors.
2. Non-fluent English: wrong word choice, poor grammar, and syntactic structure.
1. Incomprehensible: absolutely ungrammatical and for the most part doesn't make any sense.

The first attempt for labeling the datasets was conducted by senior students in the translation department. But due to the low quality of the work, the datasets were then labeled by professional translators. The labeling task was provided to the labelers through Dataturks tool, which is an online platform that provides collaborative data labeling, annotation, and segmentation.

B. Feature Sets

After comprehensive research in the literature, the following features have been selected for this work: Black box features (BBF) [16], Baseline Features (BF) [39], Fluency features (FF) [38], Adequacy Features (AF) [38], and Word Vectors (WV) [18].

The black box features are extracted from the source and target texts only such as sentence length, punctuation, type-token ration, and PoS tagging on source and target texts. This feature set is a group of 61 black box features which applies to the Arabic and English language pair.

The baseline features are a set of 17 features that quantify the complexity of ST and TT such as the number of tokens in the sentences, number of punctuation marks, language model probability in source and target language. Those features have been proven to produce good results on many language pairs [39]. Hence, the goal in this work is to test if it performs well on Arabic and English text pairs.

Fluency features are extracted from target text such as translated sentence length and coherence. For example, one of the features calculates the absolute difference between no tokens and source and target normalized by source length.

Adequacy features are features extracted from target and source text such as the ratio of the number of tokens in source and target text and the ratio of the percentage of numbers and non-content words in source and target text.

Finally, word embedding, which is an approach used in natural language processing to map words in a text to vectors of real numbers is used. Word embedding is used here to represent sentences in a format that can be fed into a machine learning model while preserving the word order and the meaning of the sentences. Working with word embedding gives us the advantage of measuring the contextual similarity between two corresponding sentences, which is a great indication for both adequacy and fluency.

For feature extraction, the first framework used is QUEST++ [40]. QUEST++ can extract a set of 130 system-independent features given the source text, target texts, and a set of auxiliary tools like POS tagger and Language Models. Features are extracted from target text to measure text fluency and from both the source and target texts to measure adequacy. While for word embedding, FastText[1] is used, which is an

[1] https://fasttext.cc/docs/en/crawl-vectors.html

open-source library from Facebook that provide word2vec models of continuous bag of words (CBOW) and Skip-gram. It also provides pre-trained models for 147 languages, including English and Arabic. In addition, the library has an aligned version of 44 word2vec models that are aligned in the same vector space, which means that the representation of each vocabulary in one language would be very similar to the representation of the vocabulary translation in a different language [18, 31]. In this work, pre-trained CBOW aligned models are used for Arabic and English with a vector dimension of 300; since all the provided vectors of the aligned models are of equal length.

VIII. Experimentation

The general architecture of a QE system shown in Fig. 1. In this research, the different ML algorithms are treated as black-box algorithms. The algorithms used are predefined in the SKLearn library [37]. The model parameters are to be chosen experimentally, using grid search and cross-validation. Different ML algorithms such as Support Vector Regression SVR and linear regression are used in order to compare and contrast results, and to produce meaningful insights on how the features correlate with the scores.

The different combinations of the QUES components are tested and evaluated, and multiple experiments are conducted. In each experiment, a different combination of features is extracted which produces a development data set of selected features extracted from selected data sources. After that the development data is split into a ratio of 80% for training and 20% for testing (evaluation). Then an ML algorithm is trained on the training data.

QUES is built using the Jupyter notebook environment. To facilitate the development of a machine learning model, the state of the art open-source library Sci-kit Learn [37] is used, due to the availability of different ML algorithm implementations, and the frequent use of Sci-kit Learn in the development of QE systems [6]. In addition, the following Python libraries are used: Gensim, NLTK, SKLearn, TensorFlow, Pandas, and Numpy.

In order to perform feature extraction, a variety of feature extractors from source texts, translated texts, external resources, and tools are used from QUEST++[40]. QUEST++ requires additional tools for the processing of the Arabic language, the additional libraries (the POS tagger, language model, etc.). Hence, Stanford OpenNLP [29] is used for segmentation, language model, POS tagging, dependency parsing and English NER,. And for Arabic NER, Madamira [36] is used. Named Entities Recognition (NER) parses unstructured text and classifies named entity mentions into predefined categories such as names, organizations, locations, etc [19].

The preservation of Named Entities (NE) is one of the desirable characteristics of a correct translation[38]. Especially when translating domain-specific texts in which it is crucial to preserve named entities. Some of the features that the framework of QE allows to consider are based on matching the number and categories of named entities in the source and target sentences.

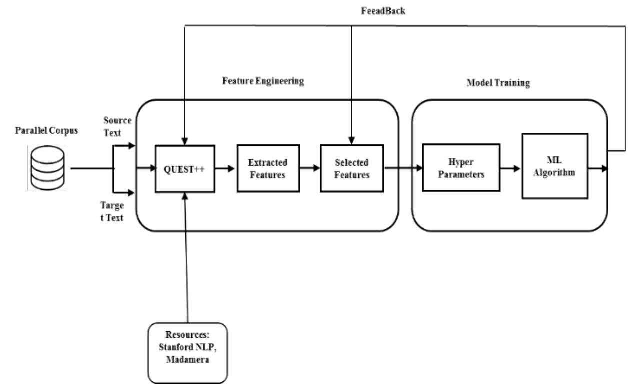

Fig. 1. General Architecture of QUES.

The extracted features were run through different ML algorithms to train different models. The models are then evaluated. Each evaluation represents an experiment, and each experiment tested the possible features' performance in predicting both the Adequacy and Fluency labels. The evaluations are measured in Mean Absolute Error (MAE) and Root Mean Squared Error (RMSE) as defined in Equations 1 and 2, respectively[11].

$$\text{MAE} = \frac{\sum_{i-1}^{N} |H(s_i) - V(s_i)|}{\text{N}} \quad (1)$$

$$\text{RMSE} = \sqrt{\frac{\sum_{i=1}^{N} \left(H(s_i) - V(s_i)\right)^2}{N}} \quad (2)$$

Where

N= is the number of test instances

$H(s_i)$ is the predicted score for instance s_i

$V(s_i)$ is the labeler score for s_i

Two sets of experiments were conducted, the first batch of experiments was conducted on individual features sets (section VII). The second batch of experiments was conducted on combined feature sets. The results of experiments and their evaluations in MAE and RMSE are listed in Tables II and III.

The second batch of experiments was set as follows:

1) Combining (BF+FF) features in an attempt to measure if increasing the number features representing fluency (in addition to a base set with features representing basic attributes both fluency and adequacy) would improve the accuracy of the predictor.

2) Combining (BF + AF) features to investigate if increasing the number of features representing adequacy (to a base set with features representing basic attributes both fluency and adequacy) has an effect on predicting translation quality of sentences.

3) Combining (AF + FF) to evaluate the model where features represent solely the adequacy and fluency of a translation pair.

4) Experimenting with all the applicable black-box features, in a group named BBF. This was done to investigate the effect of features representing all possible linguistic attributes of a translation text pair on the ability to predict translation quality.

5) The final combination set is the CF (Correlated Features), which is a set of 14 features that showed the highest correlation with the two labels.

IX. Results

In this section, the results of the experiments and the observations are discussed. First, all the sets of features produce similar results with slight variations. Second, it is observed that when only features representing fluency are extracted from the sentences, the model produces accurate results in predicting the adequacy of a translated sentence pair. This leads to the conclusion that fluency and adequacy are highly correlated in Arabic to English translations. That is also the case when using features that represent only adequacy to predict fluency. As shown by the AF and the BF entries in Table I, where both experiments produce accurate and similar results for both labels. Further calculations have been conducted to measure the correlation between the two labels, and it has been found that it reaches as high as to 0.8.

While regarding the best performing models, the results are interpreted as such: an MAE of 1.0 means that the model is of the true label by 1.0. For example, let assume that for a sentence with a true fluency label of 3.0, the system predicts a prediction label of 4.0 or 2.0. That is an acceptable result, since the labels are continuous values, and a 2.0 or 4.0 label is not far off in meaning from a label of 3.0. Third, it is observed that the best indicator for a sentence pair's overall quality is the target sentence's fluency, as the entry FF in Table I shows. The explanation behind this is the tendency for well-translated sentences to be fluent in our data set, and therefore in the real world. This observation also shows that the sentences that are dis-fluent tend to be inadequate. Fourth, regardless of the slightly better results produced by the FF group, it's observed that different feature combinations in Table III produced very similar results. The researchers believe that this is due to the size of data, which is not large enough to detect noticeable differences in performance between the different feature sets. Finally, it appears that training the models on features of word vectors doesn't perform well in Arabic-English pairs. The attempt to vectorize long sentences using a 300 long vector for each word, made the sentence and its translation reach a vector length of 53100. This caused a data sparsity problem.

X. Conclusion

This research studied the problem of translation quality estimation. The system proposed in this work has succeeded in predicting two important quality measures, fluency, and adequacy, with the best models producing a mean absolute error of 0.84 and 1.02, respectively. That proves that the features that extract the best quality indicators from text are the features representing fluency. That is due to the observation that adequate sentences tend to be fluent. This means that, generally, when a sentence is translated from Arabic to English, a low-quality translation tends to be dis-fluent in the English language. On the opposite side, high-quality translations tend to be fluent. The results of the experiment show that it is rarely the case that sentences that are adequate lack fluency. Therefore, this research concludes that in a similar setting of this work, fluency of a translated sentence on its own is an appropriate indication of a translation's overall quality.

XI. Future Work

One of the areas of improvement in this research is to increase the size of the data set. The collection, filtration, and labeling of data is a costly process, and the researches reached an economic limitation as a result of it. The researchers believe that acquiring more data will produce more accurate results as is often the case for machine learning systems. As well as allow the testing of deep learning techniques, as it solves the problem of data sparsity. Another area of improvement is to combine the labels of Adequacy and Fluency, in one general quality measure, as this research concludes that they are highly correlated, and features for one label predict the other label efficiently.

TABLE II. Experiment Results with Individual Feature Sets

Feature Set	**ML Algorithm**	**Evaluation**			
		Fluency		**Adequacy**	
		MAE	**RMSE**	**MAE**	**RMSE**
BF	Linear Regression	0.96	1.19	1.11	1.40
	SVR	0.97	1.36	1.10	1.41
AF	Linear Regression	0.96	1.187	1.11	1.43
	SVR	0.98	1.37	1.14	1.49
FF	Linear Regression	1.03	1.22	1.10	1.41
	SVR	0.84	1.43	1.02	1.42
WV	Linear Regression	2066.20	2717.49	1141.38	1485.04
	SVR	0.83	1.47	1.11	1.41

TABLE III. Experiment Results with Combined Feature Sets

Feature Set	**ML Algorithm**	**Evaluation**			
		Fluency		**Adequacy**	
		MAE	**RMSE**	**MAE**	**RMSE**
BBF	Linear Regression	0.96	1.21	1.16	1.45
	SVR	1.00	1.35	1.17	1.49
BF+AF	Linear Regression	0.95	1.19	1.06	1.36
	SVR	0.94	1.18	1.03	1.32
BF+FF	Linear Regression	0.95	1.20	1.07	1.36
	SVR	0.95	1..30	1.10	1.40
AF+FF	Linear Regression	0.96	1.18	1.11	1.42
	SVR	0.98	1.37	1.12	1.50
CF	Linear Regression	1.01	1.21	1.13	1.42
	SVR	0.89	1.33	1.14	1.47

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Classification of Freshwater Zooplankton by Pre-trained Convolutional Neural Network in Underwater Microscopy

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***Abstract*—Zooplankton is enormously diverse and fundamental group of microorganisms that exists in almost every freshwater body, determining its ecology and play a vital role in food chain. Considering the significance of zooplankton, the study of freshwater zooplankton is very essential which intensely relies on the classification of images. However, the routine manual analysis and classification is laborious, time consuming and expensive, and poses a significant challenge to experts. Thus, for recent decade much research is focused on the development of underwater imaging technologies and intelligent classification system of zooplankton. This work presents devotion to observation of freshwater zooplankton by designed underwater microscope and modeling the system for automatic classification among four different taxa. Unlike most of the existing zooplankton image classification systems, this model is trained on a comparatively small dataset collected from freshwater by designed underwater microscope. Transfer learning of pre-trained AlexNet Convolutional Neural Network (CNN) model proved to be a potential approach in the system design. Among four networks trained over two datasets, the best overall classification accuracy of up to 93.1%, comparable to other existing systems was achieved on test dataset (92.5% for Calanoid and Cyclopoid (Female), 90% for Cyclopoid (Male) and 97.5% for Daphnia). Graphical User Interface (GUI) of the model constructed on MATLAB, makes it easy for the users to collect images for building database, train network and to classify images of different taxa. Moreover, the designed system is adaptable to the addition of more classes in the future.**

***Keywords*—AlexNet; automatic image classification; Convolutional Neural Networks (CNN); freshwater zooplankton; transfer learning; underwater microscope**

I. Introduction

Zooplankton belongs to the class of microorganisms, also known as “drifters”, can be found in loads, suspended in freshwater bodies and other huge aquatic ecosystems [1]. Freshwater zooplankton community is diverse (>20 types), and occur in almost every lake, with the body size ranging from few tens of microns to >2mm. Mostly crustaceans and rotifers are the dominant group of zooplankton found in freshwater [2]. They act as a bioindicator to monitor the change in the aquatic behavior as they are very sensitive to ecological variations. Zooplankton, as a marker of determination of water quality, are also considered as integral component of global carbon cycle as well as the foundation of food chain for aquatic life [3] [4] [5]. To efficiently observe the changes in aquatic ecology and to protect it, the crucial distribution of zooplankton population cannot be left unnoticed, as it can cause appalling mutilation to aquatic ecosystem as well as undesirable communal terrestrial effects [6].

The area of underwater microscopic studies of zooplankton is an on ongoing and much focused research which is mostly linked to its taxonomic classification. Precise taxa identification offers bases for biodiversity research, which is a vital component of workflow of biological investigation along with evolution and distribution of zooplankton. However, carrying out manual research on zooplankton, which includes the sample collection by Niskin bottles or towed plankton net etc. and the manual classification by individual experts are laborious, time consuming and expensive tasks [7]. Thus, automating such tasks will help taxonomist, pharmacologist and also ease the labor of biological experts.

Few underwater imaging devices have been designed and tested for marine zooplankton studies for many years which erased the need of manual sampling by plankton nets up to major extent [8]. But the abrasive quality and size of underwater images dataset carries a challenging task in analyzing and classification due to unclear morphological traits and training of automatic classification model [9] [10]. However, focusing the critical importance of zooplankton, it is still in the interest of researchers to develop more advanced, robust and automatic system for its imaging and classification [11].

Later Section II of this paper include literature review of some imaging devices used in underwater imaging of plankton, and some recent work related to classification of zooplankton. Section III describes the methodology followed in this work, which consists of imaging of freshwater zooplankton including imaging device and method, and designing of neural network for zooplankton classification. Section IV presents training and testing results of CNN. Section V conclude the whole work, describing the summarized results, significance and future aspects of this study.

II. Related Work

A lot of effort has already been thru on imaging and automatic classification of microorganisms for last few decades [12]. Underwater imaging devices like Shadow Image Particle Profiling Evaluation Recorder (SIPPER) [13], ZOOplankton Visualization and Imaging System (ZOOVIS) [14], In Situ Ichthyoplankton Imaging System (ISIIS) [15], Underwater Vision Profiler 5 (UVP5) [16] have been in service for marine zooplankton imaging. From handcrafted feature extraction and classifier design by [17] to the most advanced approaches like deep learning by [18] have been established in different setups of zooplankton classification. Some of the recent work presented in last few years on the project of automatic classification of marine zooplankton is summarized in Table I and discussed in later section.

TABLE I. Summary of Recent Methods of Zooplankton Classification

Year	By	**Method**	**Dataset**
2016	[19]	CNN (Pre-trained CIFAR10)	WHOI - Plankton
2016	[3]	CNN (Pre-trained AlexNet and VGGNet)	ZOOscan
2017	[1]	CNN (AlexNet)	WHOI - Plankton
2017	[20]	CNN and fine-tuned AlexNet	ISIIS, IFCB, SPC
2018	[21]	CNN (AlexNet)	WHOI - Plankton
2019	[12]	CEAL and CNN (AlexNet)	ILES and CZECH
2019	[10]	CNN and Transfer learning models	WHOI, Kaggle, and ZOOscan

a. WHOI: Woods Hole Oceanographic Institution, b. IFCB: Imaging Flow Cytobot, c. SPC: Scripps Plankton Camera System, d. CEAL: Czntaining 9460 gray scale microscopic images of 13 classes. In their designed method, data augmentation technique was included to reduce the overfitting of the small dataset.

Author in [1] proposed another hybrid CNN model for plankton classification which consists of 3 AlexNet networks and fuses together at final fully connected layer. The three-channel pyramid structured network, which takes original image and two preprocessed copies of it as input respectively is trained over WHOI-Plankton dataset containing 30000 images of 30 classes.

In [20], the author experimented the behavior of CNN network trained over two very different datasets collected with different imaging devices, ISIIS and IFCB and tested over another out of domain dataset collected with SPC. CNN from scratch and fine tuning pre-trained AlexNet were chosen for experiment.

Following the preceding work by [1], [21] designed a hybrid system with addition of a concatenation layer before convolution layers, which resulted in low time cost and slightly better overall accuracy. The system was trained and tested over WHOI-Plankton dataset.

CEAL approach was presented by [12] to train a CNN for zooplankton classification. AlexNet architecture was adapted during training of CNN. In their work two dataset of images, ILES and CZECH collected by ISIIS, were used. The experiments showed that with CEAL approach there is no need for a human expert to annotate the large number of images in dataset, but just a small number of annotated images will maximize the possible accuracy of CNN.

In the work by [10], both deep learning and transfer learning approaches have been developed for plankton classification. Three major datasets, WHOI, Kaggle and ZOOscan were used during the task. They used fine-tuning and transfer learning of pretrained models and showed the possibility of pre-processing coupled with CNN in order to enhance feature extraction capability. AlexNet, GoogleNet, Inception V3, VGGNet, ResNet, DenseNet, SqueezeNet models were used and concluded DenseNet to be the best model for classification.

Unlike the proposed approach in this paper, all the previous work was carried out using publicly available large dataset of plankton images acquired during marine zooplankton survey.

III. Methodology

System flowchart shown in Fig. 1 present the key phases followed during the study of automatic zooplankton classification, which includes sample collection and observation under microscope, data acquisition, neural network training and testing.

A. Sample Collection

Freshwater samples were collected from two stations, pond and canal located in Ocean College of Zhejiang University, Zhoushan. Plankton net or any other type of plankton catcher were not used during sample collection. The water samples were kept in a glass tank without taking any biological sample preservation approaches like addition of formaldehyde solution. The samples were studied with underwater microscope designed by Ocean Optics lab. Visual data in the form of images and videos was collected from the surface and underwater observations, which confirmed the presence of several types of zooplankton as shown in Fig. 2.

Nomenclature of the zooplankton in Fig. 2 was done with the reference of “Practical guide to identifying freshwater crustacean zooplankton” [22]. Due to difficulty in distinguishing between the morphological features of zooplankton found in freshwater samples, the nomenclature is done up to the least possible level of taxonomy. Table II shows the detail taxonomy of the spotted types of zooplankton.

B. Data Acquisition

Water samples were observed through designed underwater microscope containing 14 mega pixels, Lapsun (M102) Charge-Coupled Device (CCD) camera optical chip combined with the lenses, offering total magnification of 1524x and Field of View (FOV) ranging from “1.7mm to 2.6mm”. White Light Emitted Diode (LED) lamp powered by 12-volt battery was used as lighting source. The designed microscope was vertically deployed in the sample testing glass tub and total 16 videos were captured with a frame rate of 60 frames per second. Fig. 3 shows working setup of microscope.

CCD camera's built-in function of auto focus as well as manual focus, controlled by variable objective lens ranging 1.7x to 4.5x, was used during the process of underwater microscopy. Total 2900 raw images of the size 1920x1080x3 and Joint Photographic Experts Group (JPEG) format were acquired from the microscope which contain desired Region of Interest (ROI).

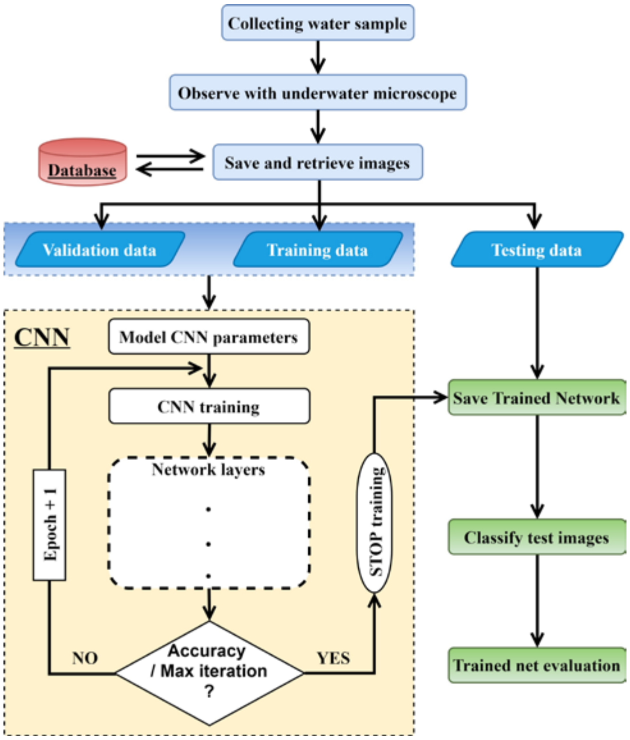

Fig. 1. Schematic Approach of the Study.

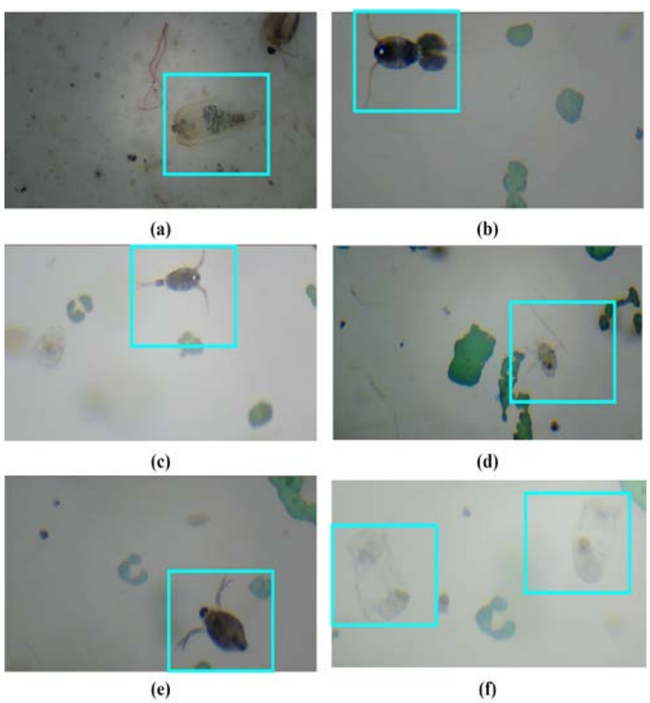

Fig. 2. Raw Images Obtained from Underwater Microscopy of Freshwater.

TABLE II. TAXONOMY OF FOUND ZOOPLANKTON TYPES

Label	Type	Taxonomy
a	Calanoid	Phylum 'Arthropoda', subphylum 'Crustacea', class 'Maxillopoda', subclass 'Copepoda', order 'Calanoida'.
b	Cyclopoid (Female)	Phylum 'Arthropoda', subphylum 'Crustacea', class 'Maxillopoda', subclass 'Copepoda', order 'Cyclopoida'.
c	Cyclopoid (Male)	
d	Cyclopoid Nauplii	
e	Daphnia	Phylum 'Arthropoda', subphylum 'Crustacea', class 'Branchiopoda', suborder 'Cladocera', family 'Daphniidae'.
f	Rotifer	Phylum 'Rotifera'.

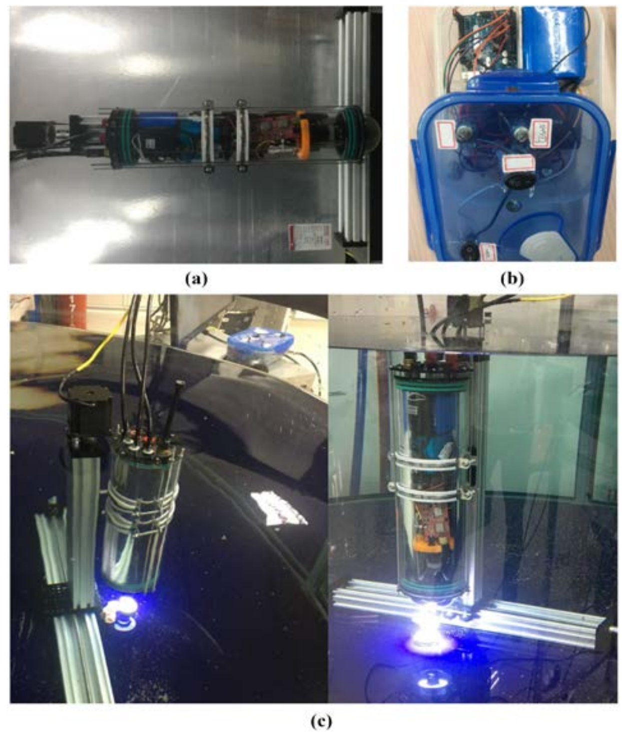

Fig. 3. Underwater Microscope Setup. (a). Imaging unit Mounted over 2-Axis Linear, Stepper-Controlled Aluminum Assembly, (b). Control unit for Objective Lens and Light Switching, (c). Underwater Microscope Operation in Testing Tank.

C. Building Image Dataset

After the screening of the acquired images, the two types of zooplankton in Fig. 2, Cyclopoid Nauplii and Rotifer were discarded from image database due to less amount and coarse quality of images. Two Image Datasets (IMDS) were built after executing the following operations.

Since microscopic images contain other particles in the image too, for example algae, thus the easiest technique to discard those noisy particles in the image is to crop desired ROI. Cropping ROI reduced the size of image, resulting quicker processing speed and low data consumption by Graphic Processing Unit (GPU) in training the model. First IMDS was created after resizing the cropped images to the new size of 227x227x3, as shown in Fig. 4, and allocating three hundred images of each type of zooplankton into four classes. Each class was named according to their taxonomy after verification with the key for zooplankton nomenclature. 80% of each class of images were used for training and remaining 20% for validation of the neural network.

Underwater microscopic images are mostly targeted by many factors that are; out of focus lens and continuous drifting of zooplankton, which cause blurry images resulting in the loss of basic morphological structure of microorganism. Second IMDS was built by including the offline augmented or the preprocessed image replicas along with the blurry raw images, keeping the dataset balanced. Thus, the total number of images in each class is increased to six hundred images per class, in which 80% were used for training and remaining for validation. Processing included contrast enhancement by contrast stretching technique and later applying Gaussian filter to smoothen the edges and get the texture of enhanced image. Sample raw images of each of four classes and processed images along with their respective histograms are shown in Fig. 5.

A separate test dataset was created containing the cropped images of the same size as that of training dataset for the accuracy estimation of trained CNN. Table III provides overall quantitative analysis of IMDS.

D. CNN Training

Proposed CNN model comprises of four different training scenarios based on IMDS, as shown in Fig. 6. Due to small dataset of images, pre-trained CNN model, AlexNet developed by [23], was adapted for this planned study. Pre-trained model is fine-tuned by replacing the final three layers with a fully connected layer of the size of number of classes, a SoftMax layer to yield the class probability calculation and finally an output classification layer. Rectified linear activation (ReLU) function is performed for each convolutional layer and fully connected layer, except for the last one which consist of SoftMax layer. Cross channel normalization layer and max pooling layer is included in the network. A dropout of 50% is used while training to prevent the network from overfitting.

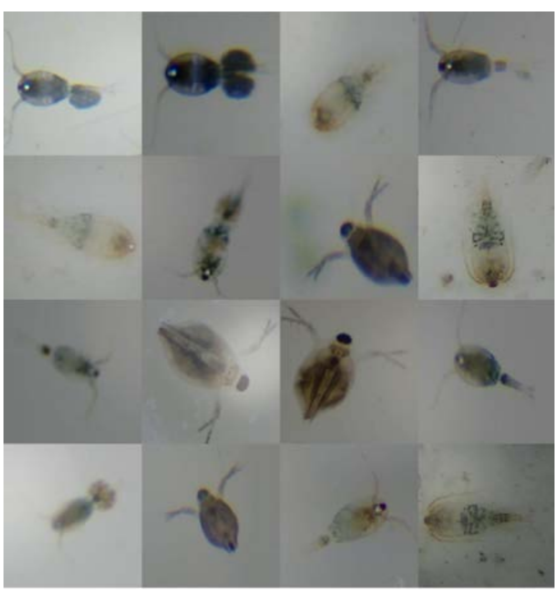

Fig. 4. ROI Cropped and Resized Images of Four Classes of IMDS.

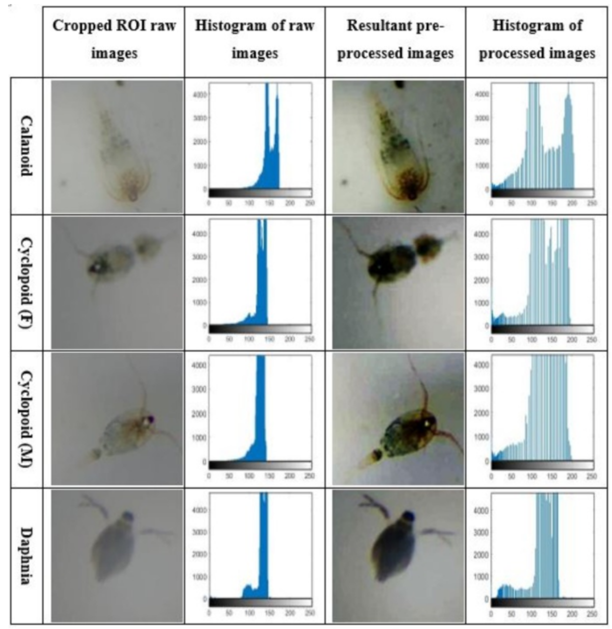

Fig. 5. ROI Cropped Images and their Pre-Processed Replicas with Respective Histogram Plots.

TABLE III. QUANTITATIVE ANALYSIS OF DATASETS

		Number of Images			
		C	***CF***	***CM***	***D***
	Raw data	500	800	700	900
IMDS 1	Fine-tuning (crop)	300	300	300	300
	Training dataset	240	240	240	240
IMDS 2	Fine-tuning (crop and preprocess)	600	600	600	600
	Training dataset	480	480	480	480
TEST	Fine-tuning (crop)	40	40	40	40

[a.] C: Calanoid, [b.] CF: Cyclopoid (Female), [c.] CM: Cyclopoid (Male), [d.] D: Daphnia.

Table IV shows the CNN configuration of hyperparameters which were selected to improve immunity of the system to overfitting during the four training models. To make fair evaluation of models' accuracies, same hyperparameters are used during the training of all the models. Lower learning rate is considered more effective during fine tuning of the pre-trained architecture.

TABLE IV. TRAINING CONFIGURATION OF CNN

Training options	**Value**
Model	AlexNet
Execution environment	GPU
Number of convolutional layers	5
Number of fully connected layers	3
Optimizer	SGDM
Mini batch size	32
Initial learning rate	0.0001
Data shuffle	Every epoch
Activation function	ReLU
Maximum iterations (IMDS 1 training)	450
Maximum iterations (IMDS 2 training)	900

[a.] SGDM = Stochastic Gradient Descent with Momentum.

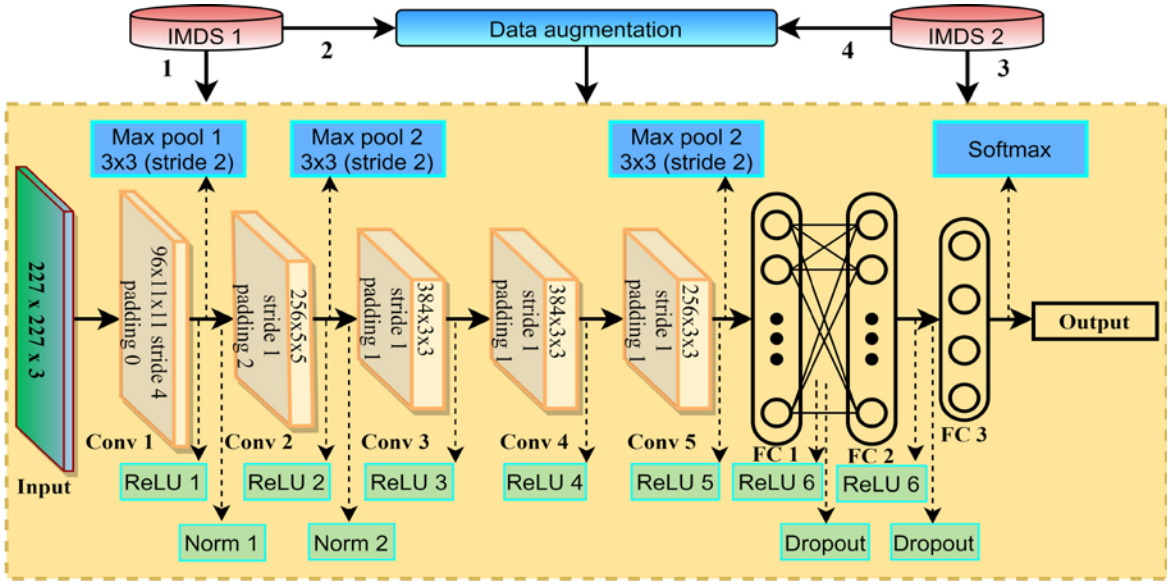

Fig. 6. Training Schematic and Network Layers Architecture.

Data augmentation was included to enhance the accuracy of the network and preventing the network to overfit. To keep the better tradeoff between validation accuracy and overfitting of data during training, only reflection of images about x-axis is selected for online augmentation of images.

IV. System Modeling and Experimental Results

Classification system was designed on MATLAB 2019a and trained over Nvidia GeForce 920MX GPU. Image acquisition, image processing, neural network, parallel computing and CUDA enabled GPU tool box were used in the modeling of zooplankton classification system.

Four networks Net1, Net2, Net3 and Net4 were trained on two datasets IMDS1 and IMDS2, keeping the same hyperparameters, and compared the results on the bases of test dataset classification. Net1 and Net2 denote the networks trained on IMDS1 with and without augmentation respectively. Similarly, Net3 and Net4 denotes the networks trained on IMDS2.

Results of all the four networks were formulated on the bases of size of dataset, training routine which shows network response to the data, confusion matrix and probability scores for each class after classification.

Precision, recall and accuracy were concluded from confusion matrix by the following equations.

Precision = TP / (TP + FP) (1)

Recall = TP / (TP + FN) (2)

Accuracy = (TP + FN) / (TP + FN + TN + FP) (3)

Another useful quantity is F-measure, which is harmonic mean of recall and precision. Its value ranges from 0 – 1, closest to 1 determines the decent grading of the network and vice versa. It can be measured as;

F measure = 2*(Recall * Precision)/(Recall+Precision) (4)

Experimental results of four networks during training and testing are summarized in Table V. Net4 yielded in to better classification results of the test data, as compared to other three networks.

Since Net4 showed better outcomes, it was considered in this study of zooplankton classification. The network was tested on in-domain test dataset which is captured with same underwater microscope. The network provided individual accuracy of 92.5% for Calanoid and Cyclopoid (Female), 90.0% for Cyclopoid (Male) and 97.5% for Daphnia as shown in Fig. 7.

TABLE V. Comparison of Neural Networks

	Net 1	**Net 2**	**Net 3**	**Net 4**
Comparison of trained CNN models based on training.				
Dataset	IMDS1	IMDS1	IMDS2	IMDS2
Images per Class	300	300	600	600
Augmentation	No	Yes	No	Yes
Training Routine	Minor OF	Smooth	Smooth	Smooth
Training Time	1.72×10^{2} s	2.44×10^{2} s	3.41×10^{2} s	5.27×10^{2} s
Validation Accuracy	98.30 %	98.80 %	98.75 %	99.58%
Comparison of trained CNN models based on testing.				
Average Recall	85.0 %	90.6 %	88.1 %	93.1 %
Average Precision	85.7 %	91.1 %	88.7 %	93.5 %
F-Measure	0.85	0.91	0.88	0.93
Testing Time	9.38×10^{-1} s	7.47×10^{-1} s	7.26×10^{-1} s	7.51×10^{-1} s

[a.] OF: Overfitting, smooth: Fine convergence of network towards data without overfitting.

[b.] Testing time is the time network takes to classify 40 images per classes and may vary with every attempt of classification. The time for training and testing is in seconds and rounded off to 2 decimal values.

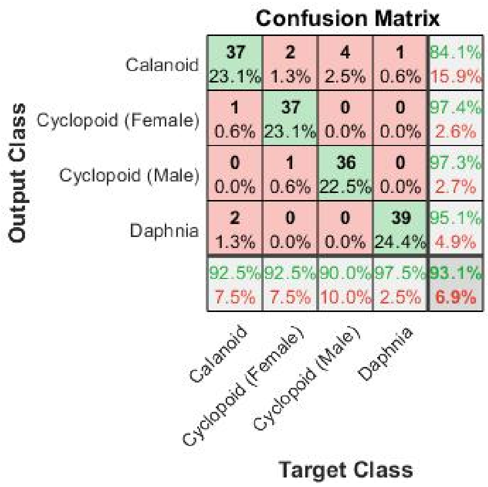

Fig. 7. Confusion Matrix of Net4.

In addition, the network yielded into much confident classification probability scores for Calanoid and Daphnia, which is 83.0% and 84.5%. The probability scores for Cyclopoid (Female), 76.2% and Cyclopoid (Male), 79.9% showed minor confusion in the classification. Fig. 8 shows the average probability scores of classifications among four classes of test dataset. Furthermore, the system showed positive response to out of domain images during classification as in Fig. 9.

GUI designed on MATLAB aids with easy routine use of the system. Developing dataset, training network and classification modules are added in GUI. Also provides results during training and probability scores during classification. Through GUI, the system can be easily modified and improved by addition of other classes for classification.

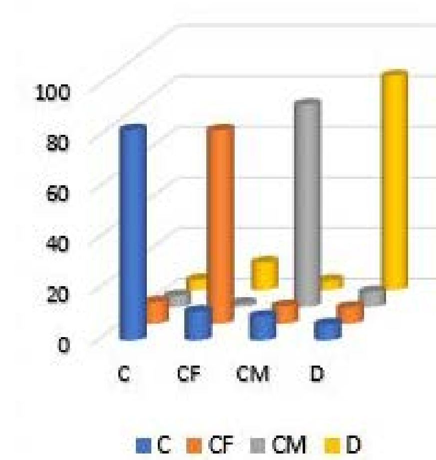

Fig. 8. Net4 Classification Probability Scores Per Class.

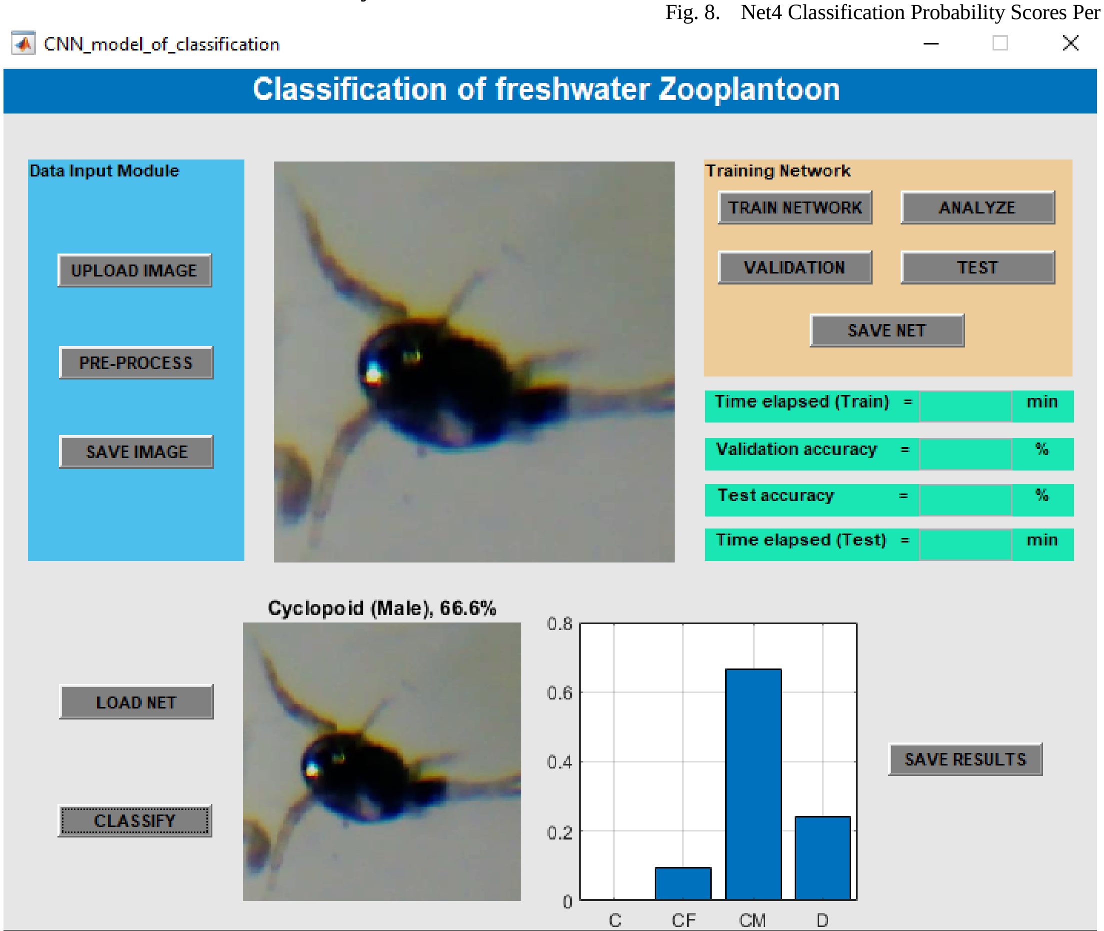

Fig. 9. GUI of Classification System.

V. Conclusion

In this study a model is propossed for operative underwater microscopy of zooplankton and automatic classification of underwater microscopic images of zooplankton. Two different and comparatively small datasets of four classes of zooplankton captured with the same imaging system were developed for the training of CNN model. The overall maximum classification accuracy of 93.1% was calculated after the trained network was tested on independent test dataset. Both online and offline data augmentation is applied in the system to enlarge the size of dataset and overcome the chances of overfitting during network training. The experimental results of architecture based on pre-trained convolutional neural network show that this system can classify zooplankton images effectively with the cost of very less time and low computing requirements.

Freshwater zooplankton distribution is very diverse and inhomogeneous and its research is of very importance in ecology protection. Main focus in zooplankton study is effective zooplankton classification which will help aquatic ecologist in robust sampling and classification without putting much efforts.

How to sample and classify zooplankton more effectively is still a big challenge and there are still many things that can be done on zooplankton imaging and classification. For future advancement in the system, much research will be focused on development of more effective and enhanced zooplankton imaging systems and designing of improved classification models. Besides, other pre-trained CNN models will also be applied in zooplankton classification systems. Also, addition of more genera as well as other aspects like life cycle stages of zooplankton into the classification model will be done.

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An Efficient Binary Clonal Selection Algorithm with Optimum Path Forest for Feature Selection

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***Abstract*—Feature selection is an important step in different applications such as data mining, classification, pattern recognition, and optimization. Until now, finding the most informative set of features among a large dataset is still an open problem. In computer science, a lot of metaphors are imported from nature and biology and proved to be efficient when applying them in an artificial way to solve a lot of problems. Examples include Neural Networks, Human Genetics, Flower Pollination, and Human Immune system. Clonal selection is one of the processes that happens in the human immune system while recognizing new infections. Mimicking this process in an artificial way resulted in a powerful algorithm, which is the Clonal Selection Algorithm. In this paper, we tried to explore the power of the Clonal Selection Algorithm in its binary form for solving the feature selection problem, we used the accuracy of the Optimum-Path Forest classifier, which is much faster than other classifiers, as a fitness function to be optimized. Experiments on three public benchmark datasets are conducted to compare the proposed Binary Clonal Selection Algorithm in conjunction with the Optimum Path Forest classifier with other four powerful algorithms. The four algorithms are Binary Flower Pollination Algorithm, Binary Bat Algorithm, Binary Cuckoo Search, and Binary Differential Evolution Algorithm. In terms of classification accuracy, experiments revealed that the proposed method outperformed the other four algorithms and moreover with a smaller number of features. Also, the proposed method took less average execution time in comparison with the other algorithms, except for Binary Cuckoo Search. The statistical analysis showed that our proposal has a significant difference in accuracy compared with the Binary Bat Algorithm and the Binary Differential Evolution Algorithm.**

Keywords*—Feature selection; artificial immune system; clonal selection algorithm; optimization; optimum path forest

I. Introduction

Artificial Immune System (AIS) uses ideas inspired by the immune system of the human body for solving different kinds of problems in various research areas like pattern recognition, data mining, machine learning, and optimization. Clonal selection is an important branch in AIS that is responsible for the response of the immune system to harmful antigens. It selects the cells (antibodies) that identified the antigens (Ag) to proliferate. Then, the procedure of affinity maturation is applied to the selected cells to improve their affinities to be suitable for the selective Ag[1]. The mentioned characteristic of the Clonal Selection Algorithm helped to make it very appropriate for solving multidimensional optimization tasks, where the optimization can be defined as a searching process for the best solution among the available solutions to a specific problem.

The target of the feature selection problem is to compose a subset that contains the best features selected among all features in a particular domain. The obtained features subset can be used to optimize an objective function of a certain problem, so the problem of feature selection can be categorized as an optimization problem. Solving this problem can be very useful in decreasing the dimensionality of the data and removing irrelevant and noisy data, subsequently, it will have a good effect on the implementation and execution of many applications.

Many natural inspired algorithms were used to find a solution to the problem of feature selection, such as Particle Swarm Optimization (PSO) [2, 3], Binary Ant Colony Optimization (ACO) [4, 5], Gravitational Search Algorithm (GSA) [6], Binary Differential Evolution (BDE) [7], Cloning Algorithm [8, 9], Artificial Fish Swarm (AFS) [10, 11], Harmony Search Algorithm (HSA) [12], Binary FireFly Algorithm (FFA) [13], Binary Cuckoo Search (BCS) [14], Binary Bat Algorithm (BBA) [15], Binary Flower Pollination Algorithm (BFPA) [16], and Binary Clonal Flower Pollination Algorithm (BCFA) [17].

The natural immune system uses the clonal selection to select the best cells that can recognize the antigens. The chosen cells are proliferated and then matured to improve their affinity to the particular antigens. The clonal selection concept has a serious role in the success of the human immune system and has an excellent ability of selection at work. As the feature selection problem can be defined as selecting the optimal subset of features to improve the fitness function of a particular problem, thus, the clonal selection algorithm was chosen in the current study to find a solution for the feature selection problem, as it has achieved good results in solving many problems of different applications. Such as function optimization [18], pattern recognition [19], scheduling [20] and industrial engineering (IE) related problems [21].

In BCSA, the search domain is designed as an *n*-dimensional, where *n* refers to the features number. The concept of the algorithm is representing each solution as a binary set of coordinates that indicate where a feature will be selected or not. The fitness function to be maximized is the accuracy of the Optimum-Path Forest (OPF) classifier [22, 23]. The point is to train the classifier and calculate its accuracy every time the solution is mutated; so fast and robust classifier should be used to handle this task like OPF that has been used in many applications and achieved good results similar to that of Support Vector Machine (SVM) classifier but OPF is faster than SVM in the training phase [15].

Although there are many algorithms that were applied to find the solutions to the problem of feature selection as mentioned above, the accuracy of the classification and the speed of execution still need to be enhanced. In this paper, we introduced a modified binary clonal selection algorithm to improve the accuracy and the speed of solving the feature selection problem, taking into consideration reducing the number of features. The proposed algorithm was compared with BFPA, BCS, BBA, and BDEA. Public UCI datasets [24] were used in the experimental results. Experiments include sensitivity analysis and execution time comparison.

The paper is sectioned as follows; Clonal Selection Algorithm is presented in Section 2. The Optimum Path Forest (OPF) classifier is explained in Section 3. The proposed Binary Clonal Selection Algorithm (BCSA) is presented in Section 4. Experimental results and discussion are demonstrated in Section 5. Finally, Section 6 contains conclusions and future work.

II. The Clonal Selection Algorithm

The biological immune system is partitioned to innate immunity and adaptive immunity, mostly, the researchers propose ideas that are based on the latter. The natural immune system has an ability to protect the human body from the attack of harmful microorganisms; it can discriminate between the normal inhabitant microorganisms and harmful ones. The harmful organisms are foreign bodies that can stimulate our immune system, so they are called antigens (Ag). The immune system of the human body produces another component called antibody (Ab) to attack each antigen, and each Ag has a specific Ab to recognize it.

There are many important models that are based on the natural immune system, like Artificial Immune Network [25], Danger Theory Inspired Algorithms [26], Negative Selection Algorithms [27–29], Clonal Selection Algorithm [1] and Dendritic Cell Algorithms [30, 31].

The clonal selection is responsible for the adaptive response of the immune system to the foreign antigens as proposed in [1], where the cells (antibodies) that detect these antigens are stimulated, cloned, and divided into plasma and memory cells. The algorithm of clonal selection can be considered as one of the evolutionary strategies that have the ability to solve the complicated problems in different areas. The features of clonal selection theory [32] can be listed as follows:

- All antibodies are mutated for maturation. The mutation can be seen as genetic changes for better recognition of antigens.
- The antibodies that carry self-reactive receptors are removed from the repertoire (the set of antibodies).
- Proliferation and differentiation for the most-stimulated antibodies.
- The best set of antibodies is chosen as memory cells for any future attacks.

The AIS algorithm [1] is explained as follows:

1) Initialize population of solutions P, some of these solutions are stored as a memory M and others are the remaining solutions Pr, so P = Pr + M;

2) The solutions *n* that achieved the highest affinity measure are selected to compose the population P_n;

3) The selected solutions *n* are cloned (reproduced), generating a clone population *C*. The rate of cloning is proportional to the solution affinity with the objective function (antigen);

4) The clone population *C* is submitted to an affinity mutation process, the rate of mutation is inversely proportional to the solution affinity with the objective function (antigen), generating a maturated population *C**;

5) From the matured population C*, reselect the highest affinity solutions to be stored in the memory part M, also some solutions of P can be exchanged with other maturated solutions of C*;

6) The lowest affinity solutions d are replaced by new initialized solutions to increase the population diversity.

In optimization problems, the objective is to look for the best solution among all available solutions, the role of AIS is to develop the solutions depending on the mechanisms of the natural immune system like clonal selection, immune network theory, or other immune system concepts. The algorithm of clonal selection optimization consists of a set of candidate solutions (antibodies) and a set of objectives (antigens), where the antibody tries to match or catch (optimize) the antigen [33].

III. The Supervised Optimum-Path Forest (OPF) Classifier

OPF is a supervised classifier that can deal with the labeled samples, it has faster training advantage than other classifiers like SVMs and ANNs [22, 23], so it is expected to be useful in the current study. OPF is a graph-based classifier in which the features are represented as graph nodes and these nodes are connected by using some adjacency relation, where the arc between two nodes can be defined as a sequence of adjacent nodes. Euclidean norm is calculated to weight the arc between every two nodes, defining a complete graph.

In the current research, the dataset is partitioned into four subsets training set Z_1, learning set Z_2, evaluating set Z_3, and testing set Z_4. The graph is represented by (Z_1, A), where the samples in Z_1 can be considered as the graph nodes and each pair of samples in $A = Z_1 \times Z_1$ can be performed as the graph arcs, as explained in Fig. 1(a), where there is a complete graph of different class samples (circles and stars). Function $\lambda(s)$ is responsible for assigning the correct class label i to any sample $s \in Z_2 \cup Z_3 \cup Z_4$. The set of prototype samples of all classes is represented by $S \subset Z_1$.

OPF classifier has three phases in its procedure [22, 23]: the training phase, the learning phase, and the classification/testing phase. In the training phase, the purpose is to generate an optimum-path forest that contains a group of discrete trees with optimum paths (OPTs) rooted in a special set $S \subset Z_1$ called prototypes. The algorithm minimum spanning tree (MST) should be applied to generate these prototypes that are samples with different class labels and have the same arcs, as explained in Fig. 1(b), where the dashed circles and stars are samples with different class labels, then the arcs that connect these samples are removed to produce a group of trees rooted in the generated prototype samples as described in Fig. 1(c), where there are two trees; one is rooted by a circle sample and the other is rooted by star sample.

The connectivity function for a path-cost F_{max} is calculated as follows [22, 23]:

$$f_{max}(< x >) = \begin{cases} 0, & if\ x \in S \\ +\infty, & Otherwise \end{cases},$$

$$f_{max}(\pi_x \cdot < x, y >) = \max\{f_{max}(\pi_x), d(x, y)\}, \tag{1}$$

In which, $d(x,y)$ represents the distance between the nodes x and y, and π is the path that can be defined as a sequence of adjacent samples where π_x is the path that ends in sample $x \in Z_1$. The path is defined as a trivial if $\pi_x = <x>$. The function $f_{max}(\pi_x .< x, y >)$ calculates the maximum distance of the path $\pi_x \cdot < x, y >$.

Now, the classifier has been initialized by the training set Z_1 during the first phase, then it will use the learning set Z_2 with Z_1 in the learning process during the learning phase. The target of this phase is learning OPF from its errors for enhancing its performance. The process starts with the training set Z_1 to initialize the classifier and generate an initial instance I that can be evaluated over the set Z_2. Then, Z_2 samples that were misclassified are selected and exchanged with random selected non-prototype samples from Z_1 to generate the new sets Z_1 and Z_2. The learning over the generated new sets Z_1 and Z_2 continues until the few iterations T are met. This technique helps in increasing the effective samples in the training set Z_1 and this is very important because this set will be used with the testing set in the final phase. Finally, the best classifier instance with the best accuracy will be employed in the final testing phase. The OPF accuracy is calculated by this equation:

$$L(I) = 1 - \frac{\sum_{i=1}^{c} E(i)}{2c} \tag{2}$$

In which, the function $L(I)$ is the classifier accuracy of the instance I, c refers to the classes number and the error function $E(i)$ is calculated as follows:

$$E(i) = e_{i,1} + e_{i,2} \tag{3}$$

Where,

$$e_{i,1} = \frac{FP(i)}{|Z_2| - |NZ_2(i)|}, \quad and \quad e_{i,2} = \frac{FN(i)}{|NZ_2(i)|}, \quad i = 1, 2, \ldots\ldots, c \tag{4}$$

Where $NZ_2(i)$ is the samples number N in Z_2 for each class i in which $i=1,2,3...c$. $FP(i)$ is the false positive, which refers to the samples number in Z_2 that were incorrectly classified as class i but they belong to the other classes. While, $FN(i)$ is the false negative, which indicates the number of Z_2 samples that were wrongly classified as being from other classes but they belong to class i. As regards to the classification/testing phase, the target is to classify the new sample by assigning a class label to it, and this is done by connecting a new sample $y \in Z_3$ (or Z_4) to all training nodes, as similar to the square shape (test sample) in Fig. 1(d). Then, the distance $d(x,y)$ between the test node y and each training node $x \in Z_1$ is calculated and used to weight the arcs. The test sample will be classified by assigning to it the class label of the training sample that achieved the minimum path-cost with it, as shown in Fig. 1(e). The path-cost $C(y)$ between the samples is computed as follows:

$$C(y) = min\{max\{C(x), d(x, y)\}\}, \ \forall \ x \in Z_1 \tag{5}$$

It can be supposed that $x^* \in Z_1$ is the training sample that achieved the optimum cost with the test sample y depending on Eq. 5. In this context, $L(x^*) = \lambda(R(y))$, where; $R(y)$ is used to get the root of sample y and the function $\lambda(y)$ is used to assign the correct class label. The classification assigns the class label of x^* as the class label of the test sample y. The classification error happens in the case that $L(x^*) \neq \lambda(y)$. The same procedure of the classification is applied to the learning samples in Z_2. However, some samples of Z_2 that were misclassified are used to teach the classifier and improve its classification performance.

OPF is explained in the following pseudo-code of Algorithm 1 that is applied to measure the solution fitness function and also when the solution is mutated to measure its new fitness function.

The algorithm receives the training and evaluating sets as input data to learn through them along with the iterations of the loop (1-10), where the classifier is trained over Z'_1 and then evaluated over Z'_2. The last best accuracy (*bestAcc*) is compared with the obtained accuracy over Z'_2 (*acc*) and in case that the latter (*acc*) is higher than the last *bestAcc*, the best instance classifier is updated with the current classifier; otherwise, the last best is kept. Then, the misclassified samples of Z'_2 are selected and exchanged with random non-prototypes samples from Z'_1. These steps continue until the stopping condition is met. By following these steps, the classifier can increase its classification quality by learning from its classification errors. Finally, the accuracy of the best classifier instance is returned and used as the solution fitness function.

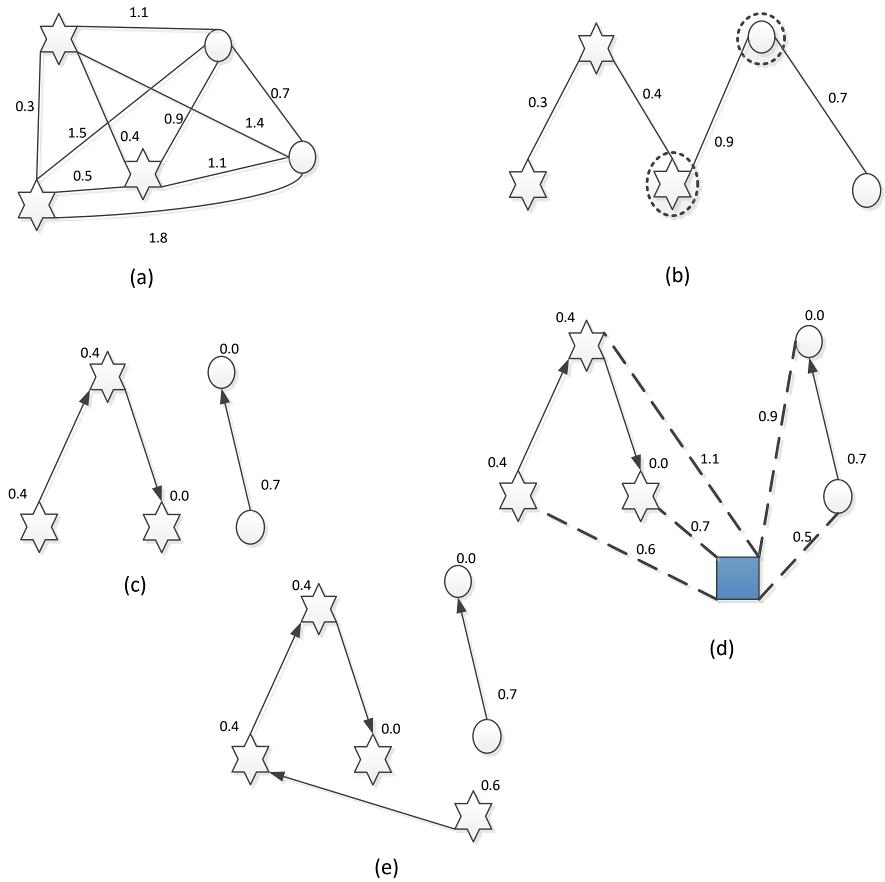

Fig. 1. A Complete Weighted Graph is Constructed by Samples with different Class Labels (Stars and Circles) of the Training Set, (b) Minimum Spanning Tree (MST) is Applied and the Prototype Samples Marked with a Dashed Circle, (c) Optimum-Path Trees (OPTs) are Generated and Rooted with Prototype Samples at the Final of the Training Phase, (d) Test Sample (Square Shape) is Connected to all the Training nodes as Expressed with Dashed Lines to Calculate the Path-Costs (e) Test Sample is Classified with the Label of the Sample that Offered the Minimum Path-Cost, so its Label is the Star Class. Note: The Values above the nodes are their Costs after Training, and the Values above the Arcs Denote the Distance between their Corresponding Nodes.

Algorithm 1: OPF Classifier Pseudocode

Input: Training set Z_1, evaluating set Z_2 and number of iterations N.

Output: The best classifier instance I.

1. While ($n < N$) **do**
2. OPF is trained over $\boldsymbol{Z_1}$;
3. OPF is evaluated over $\boldsymbol{Z_2}$ **;**
4. The accuracy of the classifier instance I is calculated using Eq. 2 and stores it in *acc* variable;
5. **If** (*acc* > *bestAcc*) **then**
6. The current classifier instance is updated to be the best instance;
7. *bestAcc* = *acc*;
8. End if
9. The misclassified samples of $\boldsymbol{Z_2}$ are exchanged with random non-prototypes samples from $\boldsymbol{Z_1}$;
10. End while
11. **Return** the best classifier instance where its accuracy represents the fitness function of the solution;

Algorithm 2: BCSA for Feature Selection

Input: Training set (Z_1), Evaluating set (Z_2), Population size (p), Number of features (f) and number of iterations (T).

Output: The best solution with the selected features that achieved the best fitness value over Z_2.

1. **For** each solution s (∀ s=1,2,....p) **do**
2. **For** each dimension d (∀ d=1,2,...f) **do**
3. $x_s^d(0) \leftarrow$ Random{0,1};
4. **End For**
5. $F_s \leftarrow -\infty$;
6. **End For**
7. **For** each solution s (∀ s=1,2,....p) **do**
8. Compose the new training set ***Z₁*** and evaluating set ***Z₂*** from the original sets Z_1 and Z_2 respectively, with the selected features $x_s^d(t)=1$, ∀d=1,2,...f;
9. $F_s \leftarrow$ Calculate the solution fitness function by applying Algorithm 1 with the new sets ;
10. **End For**
11. **While** ($t < T$) **do**
12. Select the best solutions;
13. Proliferate (clone) the selected solutions according to their affinity (fitness function);
14. **For** c = 1: n (n → all solutions in the clones population) **do**
15. Apply a random walk on each solution (mutation) in clones population to compose maturated population;
16. The fitness function of the solution is measured by applying Algorithm 1 with the new sets of mutation ;
17. **End for**
18. The highest solutions are chosen from the original and the maturated populations to compose the memory set for a next-generation ;
19. Replace solutions by novel ones (diversity introduction) ;
20. **End while**
21. **Return** the highest solution that fulfilled the best accuracy (fitness function) and its selected features will be used in testing OPF classifier (Testing phase) ;

IV. The Proposed Binary Clonal Selection Algorithm (BCSA)

In the original procedure of CSA, the solutions are updated to continuous positions, while in BCSA, the search domain is modeled as an *n*-dimensional, where *n* denotes the features number. The algorithm represents each solution (individual) in the population as a string of binary in which 1 refers that the feature will be chosen to construct a new dataset with selected features but 0 otherwise, which means that each solution encodes subset of features. The affinity function of the solution is calculated by measuring the accuracy of the OPF classifier in Algorithm 1 where each solution may have a different subset of features, so the training and evaluating subsets may be different among the solutions. The mutation process is done on each solution by applying a random walk like the distribution of Lévy flights as follows:

$$x_i^j(t+1) = x_i^j(t) + L(\lambda) \tag{6}$$

Where

$$L(\lambda) = \frac{\lambda.\Gamma(\lambda) \cdot \sin(\lambda)}{\pi} \cdot \frac{1}{s^{1+\lambda}}\,, \qquad s > 0 \tag{7}$$

In which $x_i^j(t)$ represents the solution *i* with the j^{th} feature vector, where *i=1,2,.....n* and *j=1,2,.....d*, at the iteration *t*, L(λ) is the Lévy flight step size and Γ(λ) refers to the gamma function. Each mutated solution is converted to a binary vector by employing Eq. 8 which can provide only binary values:

$$x_i^j(t+1) = \begin{cases} 1, & \text{if } S\left(x_i^j(t)\right) > \sigma \\ 0, & Otherwise \end{cases} \tag{8}$$

Where

$$S\left(x_i^j(t)\right) = \frac{1}{1 + e^{-x_i^j(t)}} \tag{9}$$

Where $x_i^j(t)$ is the mutated solution *i* with its feature vector j^{th} and σ ~ U(0,1).

The proposed algorithm deals with the selected features problem as an optimization problem where it searches for the best solution (antibody) with the best features subset that achieves the highest accuracy of OPF classifier (antigen). The pseudo-code of the proposed algorithm BCSA is explained in detail in Algorithm 2.

The algorithm initializes a population of solutions through the loop in Lines 1-6. The position of each solution is initialized by a vector of random binary values (Lines 2-4). Then, the loop in Lines 7-10 constructs the new training set $\acute{Z}_1$ and evaluating set $\acute{Z}_2$ with the selected features. After that, Algorithm 1 is applied to the newly constructed training and evaluating sets to measure the OPF accuracy to be the solution fitness function f_s. The main functionality of the proposed algorithm is explained through the iterations in Lines 11-20, where the highest solutions *n* are selected and then proliferated (cloned) according to their affinities where the cloning is proportional to the affinity, as explained through Lines 12-13. Moreover, lines 14-17 contain a loop on the clones` population, in which the mutation process (Eq. 6) is applied for each solution and this mutation is restricted by Eq. (8) for the binary values. The fitness function of each mutated solution is calculated by applying OPF classifier Algorithm 1 with the new training and evaluating sets. In line 18, the improved solutions are chosen from the original and maturated populations to produce the new population for the next iteration. In line 19, the lower affinity solutions are replaced by the newly generated random solutions to increase the diversity in the population. The algorithm ends in line 21 where the solution that got the best OPF accuracy overall runtime iterations is returned and its selected features will be used in the testing phase.

V. Results and Discussions

The proposed techniques were developed by Java language through a PC Intel Core i5 with 8GB RAM and Windows 7 operating system. The procedure of the experiment run each algorithm 10 times to get the average values, each technique in the experiment used 20 solutions for the population size, and the internal iteration number for each technique was 1000. The results of BCSA were compared to the results of BFPA, BCS, BBA, and BDEA. Table I presents the parameters of the employed optimizers.

The experiments were executed using UCI public datasets which are called the Australian dataset, Breast Cancer dataset, and German Number dataset. Table II illustrates the details that are related to the used datasets. In the current study, the datasets were randomly partitioned into four disjoint subsets Z_1, Z_2, Z_3, and Z_4. Z_1 is the training set that was used in the experiment with a percentage of 30% to initialize and train the classifier. While Z_2 is the learning set with a percentage of 20%. This learning has a serious impact on improving the composition of samples of Z_1. However, Z_3 is the validating set that was used with a percentage of 20% to ensure the efficiency of the subset of features selected. Z_4 is the testing set that was used with a percentage of 30% for finally calculating OPF accuracy with the features selected.

The methodology of the experiment depends on the threshold approach that was presented in [15]. This approach divides the running times into values range from 10% to 90%, for each period of the running time, the best solution that got the highest fitness function over Z_2 was stored in a vector. Then, the features subset of the stored solutions is used to test the validation set Z_3. After that the best-stored features subset that maximized the accuracy over Z_3 will be used to evaluate the testing set Z_4. The purpose of the validation step is to guarantee the best-selected features and ensure the quality of them before their using in the test step over Z_4, as explained in Fig. 2 [17].

Throughout the remaining of the research paper, the bold format represents the best values. Table III displays the average results of classification accuracy (fitness function) of the compared techniques over testing sets of all datasets. The obtained results revealed that BCSA surpassed the other four algorithms in all datasets.

Table IV shows the calculated standard deviation of the classification accuracy results of the compared techniques. It was demonstrated that BCSA had better results than BBA, BFPA, and BDEA in the Breast Cancer dataset. Besides, it was evident that the standard deviation of BCSA was higher than those of BFPA and BDEA in the German Numeric dataset.

The average classification errors of the different algorithms are represented in Table V. It was remarked that BCSA achieved the least classification error compared with other algorithms in the three datasets. Wilcoxon rank test [34] was calculated between the proposed algorithm BCSA and the compared techniques. The results in Table VI indicate that the BCSA outperforms the BBA over the Australian dataset (0.022) and Breast Cancer dataset (0.007) and also, surpasses BDEA over the Breast Cancer dataset (0.047), taking into account that significance level is $\alpha = 0.05$. The results in Table VII are the average of features selected by the compared algorithms over the used datasets. It is remarked that although BCSA selected the smallest number of features compared with the other techniques, it achieved the highest accuracy as shown in Table III and Fig. 3, also it achieved the lowest classification error as outlined in Table V. Table VIII shows the execution time of the used algorithms. The obtained results revealed that BCSA was executed in less time over the Breast Cancer dataset and German Numeric dataset, also it had the best mean execution time over the three datasets. The experimental results proved that BCSA outperformed the compared techniques where the best results were obtained through the classification accuracy and the number of the features selected.

The special characteristics of the clonal selection are the reason behind the exceeding of BCSA over the compared algorithms. An adaptive cloning technique, so that the high-affinity solutions are cloned by a low cloning rate, and the low-affinity solutions are cloned by a high cloning rate, this step enhances exploitation. In order not to locate in local optima, the worst affinity individuals are exchanged by randomly newly generated individuals, therefore, the algorithm always maintains the population diversity that is very important for exploration property. Also, the receptor editing helps to achieve population diversity, exploring new search regions, and avoiding local optima.

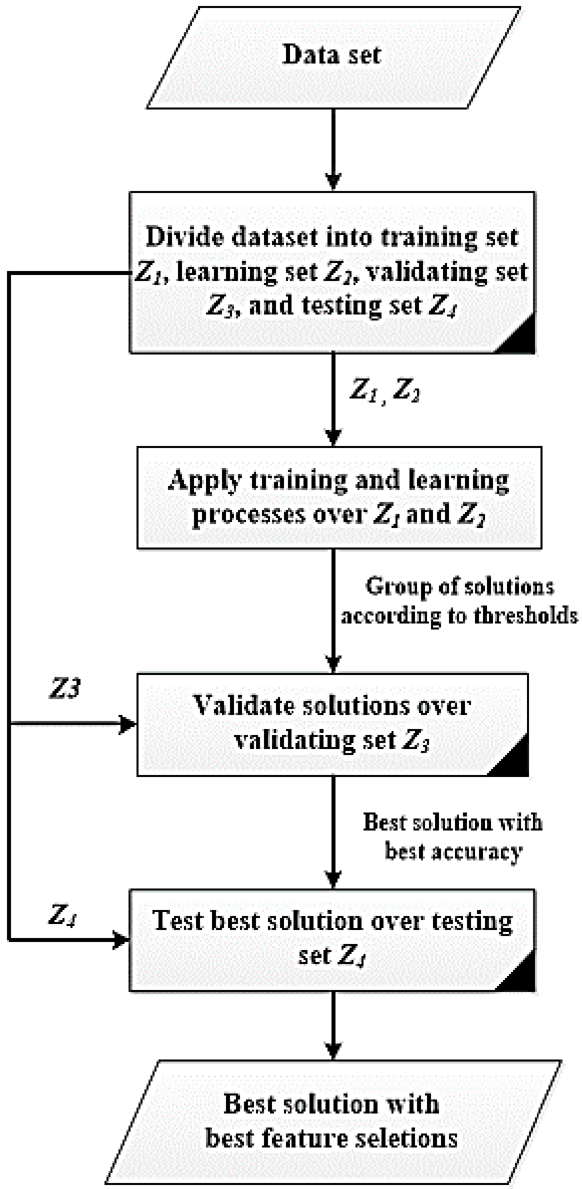

Fig. 2. Flowchart of the used Methodology in Our Experiments.

TABLE I. THE PARAMETERS OF THE EMPLOYED OPTIMIZERS

Algorithm	Parameters
BCSA	Clone population size= 10, Diversity percentage= 25 %, λ =1.5
BFPA	λ =1.5, P=0.8
BCS	λ =1.5, α=0.1, Pa=0.25
BBA	f_{min}=0, f_{max}=2, A=0.5, α=0.9, r=0.5, γ=0.9
BDEA	Cr=0.5, B=0.5

TABLE II. ATTRIBUTES OF THE USED DATASETS

Dataset Name	Number of Samples	Number of Features	Number of Classes
Australian	690	14	2
Breast Cancer	699	10	2
German Numeric	1000	24	2

TABLE III. THE CLASSIFICATION ACCURACY OF THE COMPARED ALGORITHMS FOR THREE DATASETS

Dataset Name	BCSA	BFPA	BCS	BBA	BDEA
Australian	**77.562%**	72.554%	77.315%	71.098%	74.551%
Breast Cancer	**96.262%**	95.077%	95.132%	89.175%	95.292%
German Numeric	**58.543%**	56.314%	57.094%	55.905%	56.325%
Mean	**77.456%**	74.649%	76.514%	72.059%	75.389%

TABLE IV. THE STANDARD DEVIATIONS OF THE CLASSIFICATION ACCURACY OF THE COMPARED ALGORITHMS FOR ALL DATASETS

Dataset Name	BCSA	BFPA	BCS	BBA	BDEA
Australian	7.597	6.212	5.773	**4.178**	7.040
Breast Cancer	1.171	1.960	**0.997**	7.927	1.536
German Numeric	3.959	4.889	3.823	**3.366**	4.042
Mean	4.243	4.354	**3.531**	5.157	4.206

TABLE V. THE RESULTS OF CLASSIFICATION ERRORS THAT WERE OBTAINED FROM THE DIFFERENT ALGORITHMS OVER TESTING SETS FOR ALL DATASETS

Dataset Name	BCSA	BFPA	BCS	BBA	BDEA
Australian	**22.437%**	27.445%	22.685%	28.902%	25.449%
Breast Cancer	**3.738%**	4.923%	4.868%	10.825%	4.708%
German Numeric	**41.456%**	43.685%	42.906%	44.095%	43.675%
Mean	**22.544%**	25.351%	23.486%	27.941%	24.611%

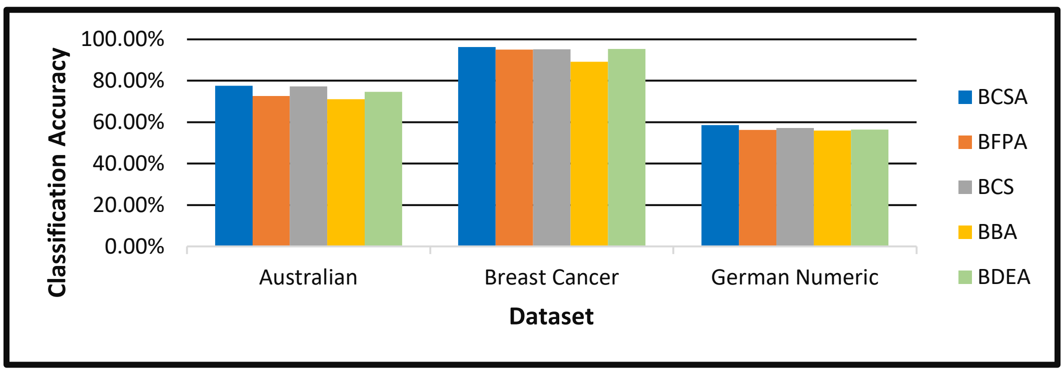

Fig. 3. The Classification Accuracy of the Compared Algorithms for All Datasets.

TABLE VI. *P*-VALUES OF THE WILCOXON TEST FOR THE BCSA AGAINST THE COMPARED ALGORITHMS FOR ALL DATASETS

Dataset Name	BFPA	BCS	BBA	BDEA
Australian	0.169	0.721	**0.022**	0.285
Breast Cancer	0.114	0.074	**0.007**	**0.047**
German Numeric	0.333	0.386	0.333	0.203

TABLE VII. THE AVERAGE SELECTED FEATURES OF THE COMPARED ALGORITHMS FOR ALL DATASETS

Dataset Name	BCSA	BFPA	BCS	BBA	BDEA
Australian	**6.7**	10.2	9.4	9.4	10.4
Breast Cancer	**6.1**	7.5	7.5	7.5	8.2
German Numeric	**15.5**	16	16	**15.5**	16.8
Mean	**9.4**	11.2	10.9	10.8	11.8

TABLE VIII. THE EXECUTION TIME OF THE COMPARED ALGORITHMS IN SECONDS FOR ALL DATASETS

Dataset Name	BCSA	BFPA	BCS	BBA	BDEA
Australian	4909.579	4826.419	**3858.050**	6137.972	3939.559
Breast Cancer	**3679.145**	7628.455	4913.337	4917.187	7612.023
German Numeric	**16373.967**	21636.725	21663.917	27059.006	26715.927
Mean	**8320.898**	11363.866	10145.101	12704.722	12755.836

VI. Conclusion

From the current research, it could be concluded that the suggested Binary Clonal Selection Algorithm (BCSA) has an ability to solve optimization problems such as feature selection problem and get notable results against four powerful techniques. The target of this problem is to look for the most informative subset of features that represent all features in a specific domain. The proposed BCSA surpassed famous techniques like BFPA, BCS, BBA, and BDEA and got the best results through the accuracy of classification, the number of features selected, and the execution time.

Therefore, it is suggested that BCSA is tested against many public datasets and real-world problems. It is proposed to be used with different classifiers like Support Vector Machine (SVM), k-Nearest Neighbors (k-NN) and Artificial Neural Networks (ANN) in order to assure its reliability. Moreover, we intend to apply it to big data mining and to solve other problems like feature weighting, job scheduling, and text processing.

Additionally, there are some ideas related to the Clonal Selection Algorithm where the ratio of the mutation can be adapted according to the individual affinity and the number of iterations. If we assumed that the population converges by times, so the mutation can have a large value at first and then decrease with time. The same concept can be applied to the ratio of cloning but in the reverse order, the ratio of the cloning can start with a small value and increase with time.

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A Machine Learning Approach for Recognizing the Holy Quran Reciter

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***Abstract*—Mainly, the holy Quran is the holy book for all Muslims. Reading the holy Quran is a special reading with rules. Reading the Holy Quran is called recitation. One of the Muslim essential activities is reading or listening to the Holy Quran. In this paper, a machine learning approach for recognizing the reader of the holy Quran (reciter) is proposed. The proposed system contains basic traditional phases for a recognition system, including data acquisition, pre-processing, feature extraction, and classification. A dataset is created for ten well-known reciters. The reciters are the prayer leaders in the holy mosques in Mecca and Madinah. The audio dataset set is analyzed using the Mel Frequency Cepstral Coefficients (MFCC). Both the K nearest neighbor (KNN) classifier, and the artificial neural network (ANN) classifier are applied for classification purpose. The pitch is used as features which are utilized to train the ANN and the KNN for classification. Two chapters from the Holy Quran are selected in this paper for system validation. Excellent *accuracy* is achieved. Using the ANN, the proposed system gives 97.62% accuracy for chapter 18 and 96.7% accuracy for chapter 36. On the other hand, the proposed system gives 97.03% accuracy for chapter 18 and 96.08% accuracy for chapter 36 by using the KNN.**

Keywords—Holy Quran audio analysis; MFCC; KNN; ANN; Machine learning

I. Introduction

The holy Quran is the holy book for all Muslims. Mainly, the Holy Quran contains 30 parts and 114 chapters where each chapter is known as Surah. The length of each chapter is different in which each surah contains a different number of verses. Some Surahs have long verses such as Al-baqarah and Al Omran have 286 and 200 verses respectively. On the other hand, some surahs have short verses such as Alikhlas, Alfalaq, and Alnas have 4, 5, and 6 verses respectively. Reading the holy Quran is a special reading mechanism where it requires some rules to be applied during the reading. The reading mechanism of the holy Quran is known as Tajweed. Quran reciters recognition has not well investigated compared to speech and speaker recognition in the English Language. The lag of Quran reciters recognition compared to speech recognition mechanism requires a unique biometric signal for each reciter may be referred to lack of uniform Quran reciters datasets [1][2]. In this paper, the speech recognition concept is exploited in recognizing the holy Quran reciters. Mainly, the recognition of Quran reciters investigation is lacking common datasets of Quran reciters. There are many fields of speech recognition including but not limited to voice calling /dialing, speech datasets indexing, exam/tests, and forensic [3]. Most of the speech recognition researchers have conducted their research on English language datasets. Little research had conducted on the Arabic language. Arabic speech recognition systems are limited compared to other languages.

Quran reciter recognition is a challenging task since it is performed with Tajweed. Each Quran reciter has his own unique signal. Each reciter signal has a temporary dynamic change over time in terms of pronunciation and the way of reciting which is known as Tarteel [4]. Recognizing and classifying the holy Quran reciters is considered an area of voice and speech recognition systems.

This paper is focused on recognizing the holy Quran reciters. A new method is applied in extracting the features using the MFCC. The remainder of this paper is organized as follows: Sections 2 presents the related work while Section 3 describes the proposed systems in detail. The experimental results are presented in Section 4. Finally, Section 5 presents brief conclusions and future work.

II. Related Work

Research on Quran reciters is limited. Al-Ayyoub et al. [1] introduced the use of identifying the right way of applying the main rules in reciting the holy Quran. Three different features were used: the MFCC, the Markov Model-based Spectral Peak Location (HMM-SPL), and the Wavelet Packet Decomposition (WPD). Furthermore, three different classifiers were used as well: the SVM, the Random Forest (RF), and the K- Nearest Neighbors (KNN). By applying the deep learning techniques, the obtained accuracy was 97.7%. Adnan Qayyoum et al. [5] introduced a deep learning approach for identifying the Quran reciter based on the recurrent neural network (RNN) by applying the bidirectional long short term memory (BLSTM) resulting in a significant result. Nahar et al. [6] introduced a Quran reciter identification using the support vector machine (SVM) and the artificial neural network (ANN). The MFCC coefficient features of 15 reciters were obtained and mapped into two different classifiers: the SVM and ANN. The system accuracy was 96.59% using the SVM and 86.1 using the ANN. Bezoui et al. [7] introduced the Quranic verses MFCCs features using MFCC. Hussaini et al. [8] presented an automatic reciter recognition system using the MFCC with a text-independent speaker recognition technique. By using their own dataset of 20 reciters, they achieved an accuracy of 86.5%. Muhammad et al. [9] developed a system for testing the people who memorized the Quran orally (E-hafiz). They extracted the features using the MFCC technique. These features were mapped into the trained collected data for matching. A mismatch error was pointed out, and the encouraging result was obtained. Alshayeb et al., [10], presented an iPhone application based on the audio fingerprinting for identifying the reciter details. Their system could show and play the reciter identified surah.

III. The Proposed System

A. Introduction

The main part of the proposed system is the feature extraction step. Upon extracting the features, these features were mapped into the ANN or KNN classifiers to recognize the reciter. Fig. 1 summarizes the proposed system model. The MFCC technique is applied for extracting the features, where these features were mapped into the ANN or KNN for training and testing to identify the Quran reciter.

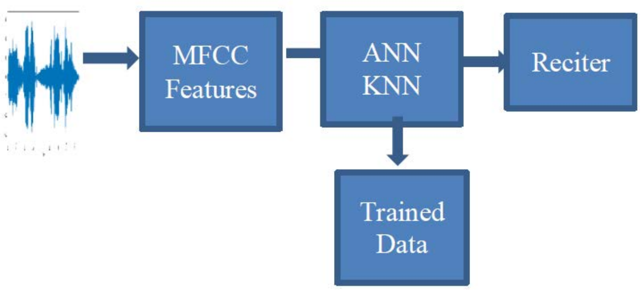

Fig. 1. The Proposed System Model.

Firstly, the trained model had built after extracting the features. Mainly, some samples of ten reciters were collected to create the dataset. The reciters are the prayer leaders in both mosques in Mecca and Madinah. Reading or listening to the holy Quran is one of the main essential activities for Muslims. It is recommended to read chapter 18 every Friday. Also, it is preferred to read chapter 36 on dead people. Two same chapters were chosen for the ten reciters. The chapters are chapters 18 and 36. Chapter 18 is Alkahf surah with 110 verses and chapter 36 is Yasin surah with 83 verses. These two chapters are common for Muslims. Table I shows ten different reciters.

In this paper, the corpus is constructed for ten reciters and two chapters. Mainly, a wave file was created for each verse in each chapter for each reciter. Each reciter recited the chapters where each verse in each chapter was saved in a wave file. Basically, in chapter 18, there were 1100 wave files due to the 110 recited verses. Similarly, in chapter 36 there were 830 wave files due to the 83 recited verses. The holy Quran contains 114 chapters, where each chapter contains (n) numbers of verses. In both chapters, the speech/audio signal for each reciter was divided into segments of 20 ms frames which was empirically chosen since the best recognition rate was achieved using it. Larger frame size did not improve the quality of recognition.

The length of the verses is different in each chapter. Due to the variation in verses length, the MFCC technique was applied for extracting the features for each verse (wave file). Basically, a 20 feature of each wave file was extracted for the 1100 and 830 acoustic waves. Basically, all the features were combined into two separate files as feature matrix files. One file for chapter 18, and another file for chapter 36. Each verse feature vector was mapped to the ANN or the KNN, respectively.

TABLE I. The Holy Quran Reciters

No.	Reciter Name	
	Name in Arabic	Name in English
1	علي الحذيفي	Ali AlHothaify
2	صلاح البدير	Salah AlBodair
3	عبدالله البعيجان	Abdullah AlBaijan
4	احمد طالب	Ahmad Taleb
5	عبدالباري الثبيتي	Abulbari Althubaity
6	سعود الشريم	Soud Alshoraim
7	ياسر الدوسري	Yasir Aldosary
8	ماهر المعيقلي	Maher Almuaiqly
9	عبدالرحمن السديس	Abudlrahman Alsudais
10	بندر بليلة	Bandar Baleelah

B. Mel-Frequency Cepstrum Coefficients (MFCC)

In general, extracting features is the first step in developing any speech recognition system. The main goal for the features is to identify the main components which represent the speech signal, and to discard all the redundant data in the speech signal. Understanding the speech/audio signal helps in extracting robust features. Understanding any speech signal needs the knowledge of the sound shape generated by reciters. Mainly, accurate determination of the sound shape yields an accurate representation of the wave file (phoneme). The shape itself comes in a short period time of the power spectrum. By exploiting the MFCC technique which is widely used in speech recognition systems, the wave file features were extracted. The Mel scale frequencies were based on the variations of the bandwidth in the human ears in capturing the characteristics of the speech [11]. In reciting Quran, the voice and the pronunciation varied from one reciter to another which yields into a tone variation.

For I = 1,2,3, 4, ………..., p

The cepstral coefficients (C_i) with an order of p, and the number of magnitude coefficients of the Discrete Fourier transform (DFT), the log energy output from the filters (X_k), using N filters. N= 20. By using equation 1, the MFCC 20 features were found for each reciter [6].

$$C_i = \sum_{k=1}^{N} X_k \left\{\cos\frac{(\pi_i(k-0.5))}{N}\right\} \quad (1)$$

C. KNN Classification

The KNN classification algorithm method is applied in this paper. Mainly, the KNN is considered a fast high-speed machine learning algorithm. The KNN is used to classify the unknown testing parameters since the training set is done as a supervised learning algorithm. To classify a reciter, the MFCC features for a specific reciter is loaded via the testing set and compared with the training features according to their distance. Later, the prediction class for the testing reciter is determined based on the minimum distance between the testing reciter and the training reciter samples by using the Euclidean distance. For example, given a query instance for a given reciter, the K nearest instances to this query reciter is the most common class. This is done according to the distance function. Basically, the KNN algorithm takes the neighborhood samples as prediction values in the testing set. This algorithm works for the minimum distance from the training set samples. The Euclidean distance D between two feature vectors X and Y is defined as follow:

$$D = \sqrt{\sum_{i=1}^{N} (x_i - y_i).^2} \tag{2}$$

where x_i and y_i are the elements of X and Y.

D. Artificial Neural Networks

Classification techniques depend on the nature of the extracted features. In this paper, the artificial neural network (ANN) is applied as a classifier. The ANN has been applied to speech recognition systems successfully. The ANN is a nonlinear system (computational model) which consists of many processing elements. In general, the ANN consists of three main layer types: the input layer, the hidden layer, and the output layer. Mainly, the input layer is the initial data for the ANN which are the extracted features. The hidden layer is the intermediate layer between the output and the input layers. All the required computations in the ANN take place in the hidden layer. The output layer generates the output of the given inputs which are the classes. Typically, the ANN accepts inputs and generates outputs based on its predefined activation function. There are various types of ANNs. In this paper, the multilayer perceptron (MLP) with the backpropagation learning algorithm was applied [12]. The ANN is used for training and recognizing the Quran reciters. Fig. 2 shows the ANN architecture.

The topology of the MLP designed for Quran reciters recognition had the following parameters:

The input layer contains features (the feature matrix).

The first hidden layer contains 20 neurons.

The second hidden layer contains 20 neurons.

The output layer contains 15 neurons.

It is worth noting that all the training was performed using the backpropagation learning algorithm.

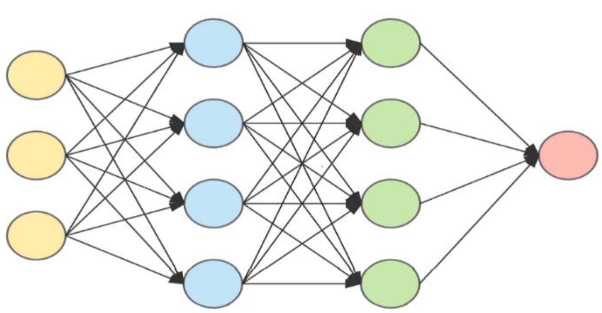

Fig. 2. The ANN Architecture [12].

IV. Experimental Results

The proposed system of the Quran reciters recognition depends mainly on the MFCC extracted features from the wave files, the learning algorithm, and on the classification. The ANN was trained with ten Quran reciters. The 20 MFCC features for the ten reciters were combined in one file. In sum, two main files were combined. One file for chapter 18 and another file for chapter 36. In our experiments, a cross-validation was used in order to verify the proposed system performance. 80% of the data were used in training, the remaining 20% of the data were used in testing. The training and testing data were chosen randomly from the combined file. Therefore, the training and the testing experiments were repeated six times of randomly selected data for training and testing in terms of 80% and 20% respectively. Table II shows the ANN and the KNN average recognition results for the reciter of Ali AlHothaify reciter in each chapter. Fig. 3 summarizes the recognition rate for the six different experiments and their average for the reciter of Ali AlHothaify reciter in each chapter.

Similar experiments were conducted for the remaining holy Quran reciters, and the average recognition rate for each Quran reciter is recorded in Table III.

TABLE II. Ali AlHothaify Reciter Recognition Rate

Experiment	Chapter 18 accuracy %		Chapter 36 accuracy %	
	ANN	KNN	ANN	KNN
1	97.5	96.9	96.8	97.1
2	98.2	97.8	97.1	96.5
3	97.8	97.1	97.4	96.8
4	98.1	97.4	96.9	96.4
5	97.3	97.1	97.1	96.7
6	97.7	97.2	96.6	96.2
Average	97.8	97.25	96.9	96.62

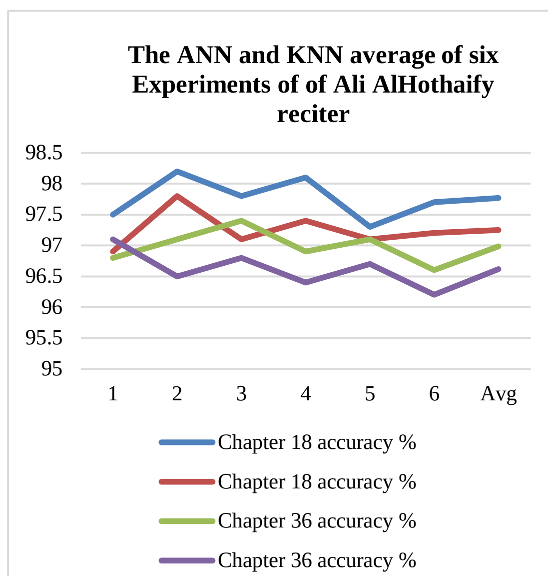

Fig. 3. The Result of the Two Chapters for Ali AlHothaify.

TABLE III. THE RECITER'S AVERAGE RECOGNITION RATE

No.	Reciter Name	Chapter 18 %		Chapter 36 %	
		ANN	KNN	ANN	KNN
1	Ali AlHothaify	97.8	97.25	96.9	96.62
2	Salah AlBodair	97.4	97.1	96.6	96.1
3	Abdullah AlBaijan	97.6	97.3	96.5	95.8
4	Ahmad Taleb	97.6	97.2	96.8	95.9
5	Abulbari Althubaity	97.3	96.8	96.3	95.7
6	Soud Alshoraim	97.9	97.2	97.2	97.5
7	Yasir Aldosary	97.8	97.1	96.9	95.8
8	Maher Almuaiqly	97.9	97.1	96.9	96.1
9	Abudlrahman Alsudais	97.4	96.9	96.2	95.4
10	Bandar Baleelah	97.5	97.1	96.7	95.9
Average		97.62	97.03	96.7	96.08

Table III shows that the average ANN accuracy is 97.6% and 96.7% for chapters 18 and 36 respectively. Almost 2.5% and 3.5% of the entire data were misclassified. Furthermore, it shows that the average KK accuracy is 97.03% and 96.08% for chapters 18 and 36 respectively. The main reason for misclassification was the way of reading and reciting different verses. In addition, the tone variation and the expressed emotion of the reciter with the verse are critical. This is due to the reciting rule of Tajweed where all reciters follow the same rules.

In comparison with the existing work, it is difficult to compare the performance of the proposed system to other existing similar systems in [2,5,6] since other criteria and other datasets were used there. Basically, the existing work used different reciters and different datasets. Table IV summarizes the performance of the existing systems and the proposed system.

TABLE IV. PERFORMANCE OF EXISTING SYSTEMS

System	Method	Accuracy rate %
Rehan Ullah Khan, et al [2]	Naïve Bayes	81
	J48	78
	Random Forest	78
Adnan Qayyoum et al [5]	KNN	86.2154
	RF	88.4324
	DT	86.8865
	LR	87.9062
	SVM	89.3965
	BLSTM	99.8992
Khalid M. Nahar et al [6]	SVM	86.17
	ANN	83
Proposed System	ANN	97.62(ch. 18)
		96.7 (ch. 36)
	KNN	97.03(ch. 18)
		96.08 (ch. 36)

V. CONCLUSION

In this paper, a machine learning approach for Quran reciters recognition was proposed by using the KNN and ANN classifiers. The performance of both classifiers the KNN and the ANN were reported. Basically, the MFCC features were extracted and mapped into the ANN for both training and testing. Two common chapters were selected by ten famous reciters in Meccca and Madinah. The obtained average recognition rate for the whole reciters were 97.6 and 96.7 for chapter 18 and 36 respectively using the ANN. However, the obtained average recognition rate for the whole reciters were 97.03 and 96.08 for chapter 18 and 36 respectively using the KNN. In the future, in order to improve the system performance and to increase the system accuracy, it is suggested to apply the sliding window features to the wave signals with other classification algorithms such as, the Hidden Markov Models (HMMs).

ACKNOWLEDGMENT

Since appreciation is expressed to the librarians in the holy mosque in Madinah for providing us with CD ROM for the holy mosques reciters in both Mecca and Madinah.

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Modeling and Performance Analysis of an Adaptive PID Speed Controller for the BLDC Motor

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***Abstract*—Brushless Direct Current (BLDC) motor is the most popular useable motor for automation and industry. For good performance of the BLDC motor hunger driving circuit but the driving circuit is costly, complex control mechanism, various parameter dependency and low torque. The Proportional Integral (PI), Proportional Integral Derivative (PID), fuzzy logic, adaptive, Quantity Feedback Theory (QFT), Pulse Width Modulation (PWM) controller are the common types of control method existing for the BLDC motor. This research explores some well-working experiments and identified the PID controller as far more applicable controller. For well efficacious and useful in getting satisfied control performance if the adaptability is implemented. This research proposed a combined method using PID and PID auto tuner, having the ability to improve the system adaptability, given the method named as adaptive PID controller. To verify the performance, MATLAB simulation platform was used, and a benchmark system was developed based on the actual BLDC motor parameters, auxiliary systems, and mathematically solved parameters. All work has done by using MATLAB/ Simulink.**

Keywords—QFT; PWM; BLDC motor; PID controller; adaptive; adaptive PID controller; APIDC

I. Introduction

Brushless DC motor is getting more popular and operational motor than the other DC motor. It requires less maintenance and can have a life span as it has no wearable brush and has level speed-torque properties, high productivity. In driving, from an assortment of motors, BLDC motors have been generally utilized in automated, restorative hardware, vehicles, aviation, hard circle drive, as the benefits of BLDC are extraordinary execution, advance and lower assurance in power factor. The BLDC motors are increasingly costly, and its controller design is more complex [1]. Also, need to focus on BLDC motor safety and inverter because it delivers a high risk of security issues, demagnetization problem and inverter disappointment. Controlling the motor speed of the BLDC requires the controller circuit framework for good productivity. Numerous kinds of speed control frameworks have been produced for controllers, yet speed controllers must be refreshed with age. Right now, there are two circles for speed control of the BLDC motor. For instance, the electronic force motor speed controller for the inward circle tuning and an outside circle for inverter permits the very voltage of the DC vehicle [2]. To control this framework, the DC supply required relies upon the motor RPM and its capacities. The sensor is the most significant piece of the controller for controlling the motor speed. The sensor can stream directions. The inverter used to change over DC voltage to AC voltage likewise has a DC voltage converter to change over DC to this framework. In any case, when utilizing a brush dc motor, mechanical rubbing, and electrical erosion mess some up which urge the inclination to utilize brushless dc (BLDC) motor. These days, BLDC motors are generally utilized in electronic vehicles, because the nonattendance of a brush/transport gathering decreases hearing sharpness and improves productivity and torque [3]. A well-known magnet brushless DC motor (PMBDCM) is mainstream and utilized BLDC motor utilized as a variable speed drive framework for mechanical, car, aviation, and computerization applications. The rotor is made electronically rather than a stator and a permanent magnet and computation brushless. There are two types of brushless motor: Namely, brushless AC motor and brushless DC motor. The brushless AC motor (perpetual magnet simultaneous motor) and the brushless DC motor rely upon the current frequency. The brushless AC motor is consumed by the sinusoidal current while the brushless DC motor is consumed by the rectangular stream [4]. Studies have been directed to quantify force swell in brushless DC motor [5]. It is unordinary for papers to depict the estimation of electromagnetic force delivered by a brushless DC motor utilizing current stage information. Motor force can be estimated straightforwardly by a force sensor which can be costly and can now and again be overwhelming when applied to explicit applications. Assessments of electromagnetic force with quantifiable limits, for example, back EMF, rotor speed and stage current are deeply alluring [6]. The electromagnetic force of a brushless DC motor can be assessed by estimating the stage movements by asserted that in any event two current sensors were expected to assess the electromagnetic force. Initially, these procedures were utilized legitimately as BLDC motor controllers. Immediately, the FLC was applied to control the speed of the BLDC motor [7]. It is described by its capacity to manage inadequately characterized numerical models. The FLC rules required to make control directions rely to a great extent upon the human experience. Notwithstanding, FLCs require additional time than regular control strategies, for example, PI and PID to determine complex fuzzification and cleansing procedures [8]. In this research applied two types controller one is PID controller another one is PID-Auto tuner both are combined, and it called adaptive PID controller. This study aims to develop a controller drive to control BLDC motor speed and torque and compare controller output result with benchmark controller. This works done by using MATLAB/ Simulink.

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This article is organized into five distinct sections. After the abstract, the article starts with the introduction as Section I discusses BLDC motor and its control system. Section II introduces and discusses the basic models of a BLDC motor and speed control systems. In Section III, the method and the MATLAB simulation model are discussed in detail. Section IV is illustrated by graphical results obtained from MATLAB models of Section III. Finally, this research article is concluded by a conclusion, Section number V.

II. Basic Model and Speed Control of BLDC Motor

Fig. 1 shows the basic model of the Adaptive PID controller. To develop motor controlling controller many scholars, follow the different method and technic. In this research also apply another technic to increase the motor speed. For better output efficiency of the BLDC, motor speed control is very impotent in this situation. So, solved this problem and get better efficiency proposed this basic model. The motherboard has a three-triode power converter, as it conveys six force transistors all the while on a BLDC motor. The MOSFET transistors have a rotor position, which will be characterized as the exchanging succession. The starter is the objective of each of the three gadget gadgets. The Hall sensor is the data that the decoder square creates in the EMF of the reference current sign vector. Enacting the switch side of the invert flows for the contrary side of the moving motor.

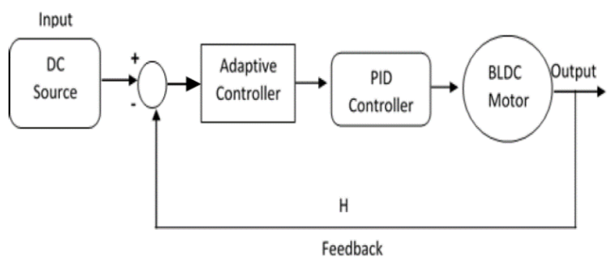


Fig. 1. Basic Block Diagram of an Adaptive PID Controller.

III. Controller and Research Method

The proposed controller was simulated by the MATLAB simulation process, but the controller needs to develop mathematical equations and monitor the performance of simulation-based.

A. *Proposed Adaptive-PID Controller*

The Adaptive PID auto-tuner is the combined controller, that working in a series of PID and PID auto-tuner controller. This combination of the combined controller has the adaptability over any circumstances, as like the increasing number of input decision change. The Adaptive PID auto-tuner block is containing both controllers in series. In Fig. 2, the Adaptive PID auto-tuner controller is shown with the motor transfer function and inside the Adaptive PID auto-tuner controller block, where both controllers are connected in series.

B. *FPA based BLDC Speed Controller, Benchmark Paper*

One of the researches has done on Flower Pollination Algorithm (FPA) for speed control of BLDC motor with optimal PID tuning [9]. In that work, the optimization-based approach is applied for tuning of PID speed controller by considering an integral square error as the objective function. This model also followed the cascade mode, the speed control loop and voltage control loop. Both controllers followed the PID basic controller inside where FPA method algorithm was developed. Though the method looks good, on the benchmark platform it was giving overshoot which is higher than a normal phenomenon. Fig. 3 shows the FPA speed controller.

C. *Equations*

The model of the armature contorting for the BLDC motor is communicated as pursues:

$$v_a = Ri_a + L\frac{di_a}{dt} + e_a \tag{1}$$

$$v_b = Ri_b + L\frac{di_b}{dt} + e_b \tag{2}$$

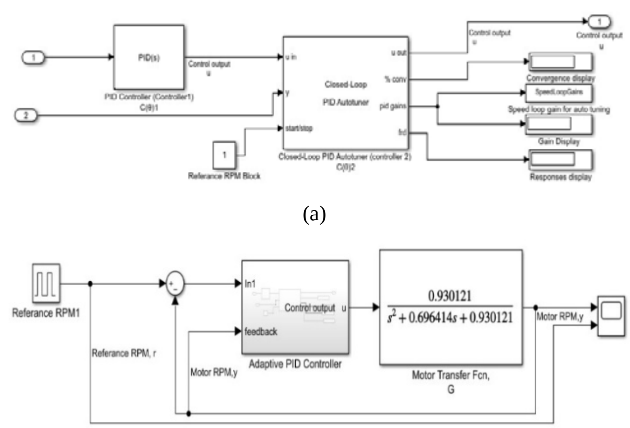
$$v_c = Ri_c + L\frac{di_c}{dt} + e_c \tag{3}$$

where L is armature self-inductance [H], R - armature resistance (Ω), v_a, v_b, v_c - terminal phase voltage (V), i_a, i_b, i_c - motor input current (A), and e_a, e_b, e_c - motor back-emf (V). The equivalent circuit for one phase is represented in Fig. 4. In the 3-stage BLDC motor, the back-emf is identified with an element of rotor position and the back-emf of each stage has 120 degrees stage point distinction so the condition of each stage ought to be as per the following:

$$e_a = \mathrm{Kef}\,(\theta e)\,\omega \tag{4}$$

$$e_b = \mathrm{Kef}\,(\theta e - 120)\,\omega \tag{5}$$

$$e_c = \mathrm{Kef}\,(\theta e + 120)\,\omega \tag{6}$$



(a)

(b)

Fig. 2. MATLAB Model (a) Adaptive PID Auto-Tuner Controller in Close-Loop System and (b) Inside Adaptive PID Auto-Tuner Block.

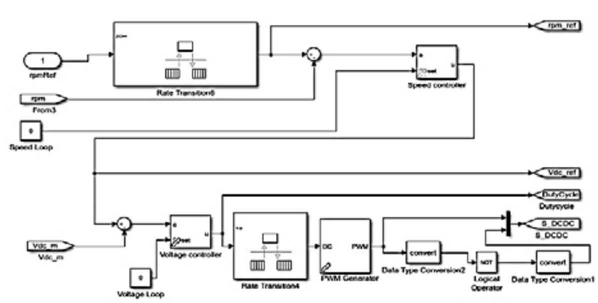


Fig. 3. The FPA based Controller for BLDC.

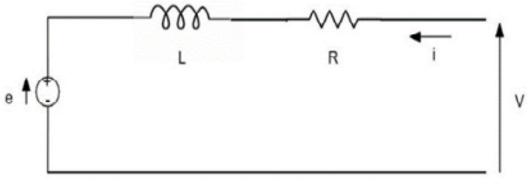


Fig. 4. Equivalent Circuit of the BLDC Motor for One Stage.

where K_e is back-emf constant (V/m – RPM)1, θe - electrical rotor angle (e – degrees), ω - rotor speed (m – RPM).

The electrical rotor point is equivalent to the mechanical rotor edge duplicated by the number of post sets p:

$$\theta e = p\theta m \quad (7)$$

where θ_m is the mechanical rotor edge (m – degrees).

The absolute torque yield can be spoken to as a summation of that of each stage. Next condition speaks to the all-out torque yield or electromagnetic torque:

$$T_e = \frac{e_a i_a + e_b e_b + e_c e_c}{\omega} = K_T \frac{3}{2} i_q \quad (8)$$

where T_e is total torque output (N_m), K_T - motor constant (Nm/A), i_q - quadrature current (A).

D. Simulation Model for the Proposed Controller

Fig. 5 shows the overall simulation model of an adaptive PID controller with connected 3-phase BLDC motor with Load. There are many parameters used to design this controller also used mathematical equation in this controller. At first, fixed reference R.P.M than reference rpm and load connected with the controller. There are two types of controller used one is PID and another one is the adaptive controller. After completing all mechanism than signal comes to MOSFET drive and then comes buck converter.

A buck converter (step-down converter) is a DC-to-DC power converter that brings down the voltage (while streaming current) from its information (supply) to yield (load). Its also connected with DC voltage source, motor and output connected with 3-phase inverter and voltage sensor. An inverter connected with IGBT drive and current sensor. Current sensor connected with BLDC motor.

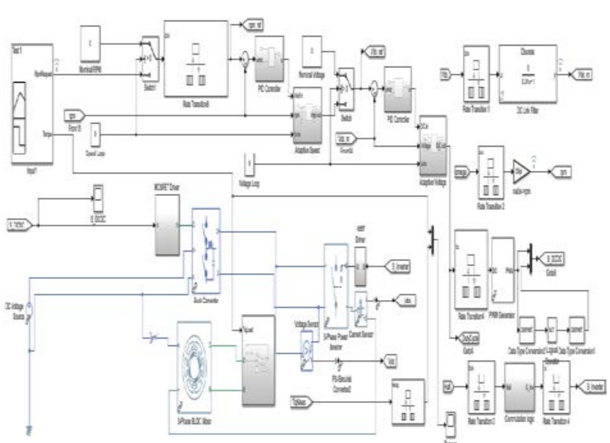


Fig. 5. Proposed Simulation mode of Adaptive PID Controller.

IV. Result and Discussion

A. Controller Output Applying 24 V, Torque T_e-10 N-m for 1000 RPM

Fig. 6 and Table I shows the adaptive PID controller output. This output with torque load T_e, 10 N-m and its supply voltage is 24 DC volt. The output of the controller had no overshoot and undershoot is 45% (24V/unit), settling time 1seconds (0.1 seconds/unit) and had no steady-state error after 3secs this is not at the stable point. The performance indicates that the adaptive PID controller has satisfactory controllability than the existing other controller but still it can improve. So, the results of the proposed adaptive PID controller simulation model for the BLDC motor speed control.

B. Controller Output Applying 48V, Torque T_e-10 N-m for 1000 RPM

Fig. 7 shows the adaptive PID controller output. This output with torque load T_e 10 N-m and its supply voltage is 48 DC volt. The output of the controller had an overshoot of 0.497% and undershoot is 1.833% (48V/unit), settling time 0.35 seconds (0.1seconds/unit) and had no steady-state error. The performance indicates that the adaptive PID controller has very good controllability than the existing other controllers. So, the results of the proposed adaptive PID controller simulation model for the BLDC motor speed control. This research conducts the mathematical modelling for 1000 RPM for that motor. Here the simulation results are shown in Fig. 7 and the are shown in Table II.

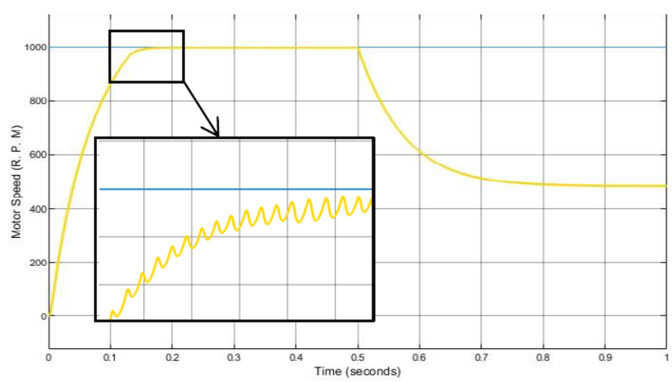


Fig. 6. The Output of the Adaptive PID Controller Applying 24V.

TABLE I. SIMULATED MEASUREMENTS FOR 24 V

Measurements	**Time**
Rise time (With load)	0.034319s
Max / Min high (Without load)	999.99 RPM / 997.3 RPM
Max / Min high (With load)	483.5 RPM / 482.7 RPM
Without load RMS	998.5 RPM
With load RMS	482.4 RPM
Without load overshoot	No
With load E_{ss} (Steady State Error)	51.76%

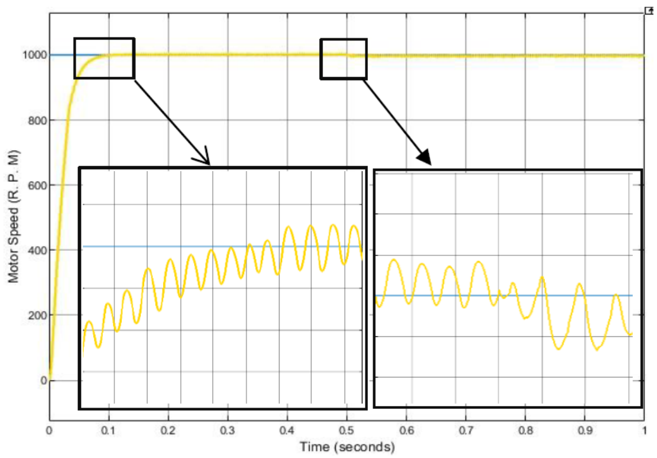


Fig. 7. Output of the Adaptive PID Controller Applying 48V.

TABLE II. SIMULATED MEASUREMENTS FOR 1000 RPM

Measurements	Time
Rising time	31.386 ms
Max / Min high	1001 RPM /993.939 RPM
With load maximum high	999.3 RPM
Overshoot	0.452%
With load overshoot	0.197%
With load undershoot	1.833%

C. FPA Speed Control System, Applying 48V, Torque Te 10N-m for 1000 RPM

The Flower Pollination Algorithm (FPA) also one of the popular controllers already describes in Fig. 3. This controller is one of the smooth performance controllers, can be used for any slow process system. Fig. 8 shows the performance of the FPA controller performance. The controller gave 1098 RPM having unexcitable overshoot of 9.34%. While applied load, it again gave 3.646% undershoot, but with time smoothly came back to the required line. When, the sudden load applied to the system, immediately a high undershoot and overshoot formed due to its slow response. This response is not only for this system, but most of the research also found the same issue. The controller is perfect for a system, where slow response and steady performance is required. The performance specifications are given in Table III for better understanding.

TABLE III. FPA BASED SPEED CONTROLLER PERFORMANCE ON THE SIMULATION PLATFORM

Measurements	Time
Rise time (With load)	0.03415s
Max / Min high (Without load)	1098 RPM / 998.7 RPM
Max / Min high (With load)	1038 RPM / 994.5 RPM
Without load RMS	1003 RPM
With load RMS	1001 RPM
Without load overshoot	9.34%
With load undershoot	3.646%

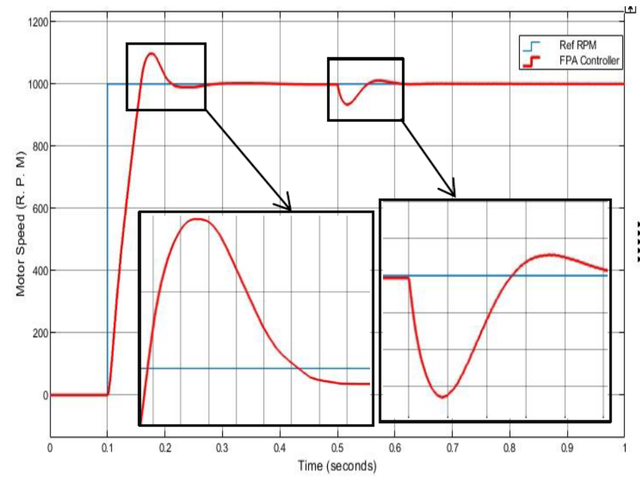


Fig. 8. FPA Speed Controller Output Applying 48V.

D. Compare with Benchmark Controller

Fig. 9 shows the adaptive PID controller output and FPA speed controller output. This output with load condition and its supply voltage is 48 volts. Reference rpm is 1000 after running the output of the adaptive PID controller had an overshoot of 0.197% and undershoot is 1.833% (48V/unit), settling time 0.05 seconds (seconds/unit) and had no steady-state error. On the other hand, the FPA speed controller had an overshoot of 9.34% and undershoot is 3.646% (48V/unit), settling time is unknown and had a steady-state error. The performance indicates that the adaptive PID controller has good controllability than the existing others So, The results of the proposed adaptive PID controller simulation model for the BLDC motor speed control. The Pre-shoot, overshoot and undershoot can be reduced mainly by using a high-frequency noise and filter [10].

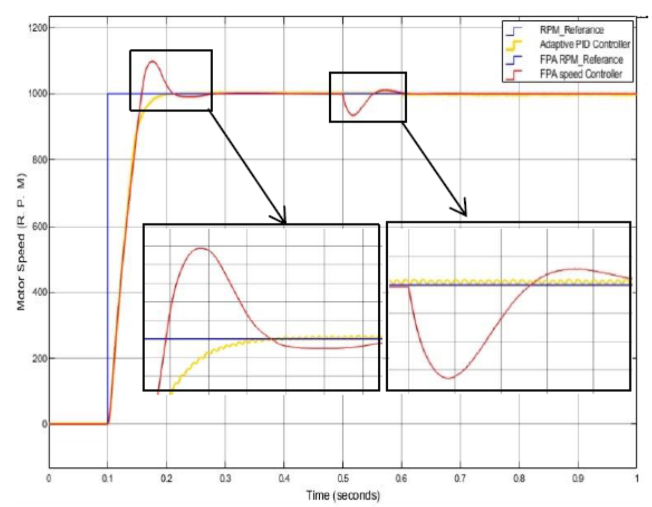


Fig. 9. Adaptive PID and PFA Speed Controller, Applying 48V, Te-10 N-m.

V. CONCLUSION

This controller design for three-phase BLDC motor for its speed control. An adaptive PID controller technology has more advanced to control BLDC motor. As a result, an adaptive PID controller gives excellent Simulation results than the other controller system. However, it is worth noticing that when the motor functions at up and down speeds, for it to be well responsive, the motor speed must be continuous when the load will change. This research aims almost completed but still need to remove it noise for smooth speed control. The aims of the study will be developed a Prototype control drive using this adaptive PID controller to control BLDC motor speed. This simulation work helps to developed BLDC motor speed and efficiency.

VI. Future Work

This research primarily has been developed a basic foundation of the proposed adaptive PID speed controller for the BLDC motor, and verified the design by simulation successfully. Further experimental tests can be conducted in the future for a detailed evaluation of this research and to further strengthen the claim of its achievement.

Acknowledgment

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Fast Side Information Generation for High-Resolution Videos in Distributed Video Coding Applications

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***Abstract*—Distributed video coding (DVC) is an attractive and promising scheme that suits the constrained video applications, such as wireless sensor networks or wireless surveillance systems. In DVC, estimation of fast and consistent side information (Sį) is a critical issue for instant and real-time decoding. This issue becomes even more serious for high-resolution videos. Therefore, to minimise the side information estimation computational complexity, in this work, a computationally low complex DVC codec is proposed, which uses a simple phase interpolation (Phase-I) algorithm. It performs faster for all resolutions videos, and significant results are achieved for high-resolution videos with a large group of pictures (GOP). For the proposed technique, the computation time rapidly decreases with an increase in resolution. It performs 221% to 280% faster from conventional frame interpolation method for high-resolution videos and large GOP at the cost of little degradation in the visual quality of estimated side information.**

Keywords*—*Fast side information algorithm; phase-based interpolation (Phase-I); DVC; DVC decoder for high-resolution videos; real-time DVC decoding; real-time side information

I. Introduction

Wireless video sensor networks (WVSNs) are capable of capturing video at distributed video sensor nodes. Conventional video codecs are ill-suited for these nodes. Compression of the captured video has received significant interest in literature. The availability of high-resolution CMOS image sensors at low cost makes the WVSNs more trending [1], especially for real-time surveillance and environment monitoring [2, 3] and medical applications [4], etc. The new applications of WVSN are emerging very rapidly and demanding efficient pre-processing and transmission [5]. Due to challenges of being battery supported, there is a need for efficient use of storage resources and lower energy consumption in WVSNs [6]. Such video sensors, therefore, demand low encoding techniques to compress the video to the lower bit rate before storing or transmitting it [7] and to reduce the transmission delay [8]. One of the supportive coding approaches is distributed video coding (DVC) that redistributes the coding complexity in such a way that there is much low encoding computation [9] while decoding can be more complex [10].

In DVC codecs, the frames are organised in a group of pictures (GOP) of size 2, 4 or more. The key-frames are Intra-encoded first and then transmitted, and intermediate frames are WZ encoded. At the decoder, these WZ frames are estimated by the Intra-decoded key-frames. These DVC coding schemes achieved high compression while maintaining low encoding complexity by utilising the Intra-encoding at the encoder, and Inter-decoding (because the Sį estimation depends on key-frames) at the decoder [11]. The DVC encoder is deliberately kept computationally very simple but the decoder is computationally very complex since it needs to accurately estimate the replica of the WZ frames known as side information (Sį). The traditional Sį generation algorithms are computationally extensive due to the complex nature of the prediction process and take a lot of time even for a low-resolution video.

A. Motivation and Contribution

The Sį is estimated either by interpolation or extrapolation, and its quality determines the overall coding efficiency of codec [12]. Both prediction processes are considered to be time-consuming [13] activity of the decoding process. The huge computational complexity [14] is associated with these prediction processes, and it takes considerable time even for the low-resolution videos, and the decoding process slows down due to it [13]. The efforts were carried out mostly on low-resolution 1k-pixel and 176x144 pixels per frame videos [15] to improve the RD performance. The researchers are putting an effort to design the framework to achieve the low complex and real-time decoding for such low-resolution video [15] while achieving a consistent and high RD performance comparable with conventional codec.

As a low-cost standard definition (SD) and high definition (HD) mini video sensors [16] are widely available, so there is a need for real-time DVC decoding framework for such high-quality videos. However, no DVC framework for real-time or fast Sį generation is found in the literature for high-quality videos. Therefore, herein, an attempt is made to design a suitable DVC framework with low computational Sį generation algorithms for high-quality videos. In this work, a Phase interpolation (Phase-I) is incorporated for Sį generation in the DVC decoder.

The rest of the paper is organised as follows: Section II discusses the background, and Section III describes the proposed DVC model for fast Sį generation for high-resolution videos. In Section IV, results have been presented, and the performance of the proposed model in terms of computational complexity and quality analysis with (peak signal to noise ratio) PSNR is discussed. In Section V, the future directions are proposed. Finally, the conclusion is in Section VI.

II. Background

The DVC [17] structure follows the Slepian Wolf [18] and Wyner-Ziv [19] theories proposed in the early 1970s. These theories proposed that the correlated sources can be independently encoded and jointly decoded. This way, they can still achieve the same rate as they are jointly encoded and decoded as long as the correlated Sị is available and used in the decoder side. In WVSN, the video sensor nodes acquire frames at some rate, and the consecutive frames are highly correlated. These correlated frames are independently encoded because the prediction loop is not involved in the DVC encoding process, and that is how the DVC provides codec-independent scalability.

DVC compression efficiency highly depends on Sị quality [20]. It is important to remember that high-quality Sị leads to better rate-distortion (RD) performance [21, 22] which plays a significant role in achieving low bit rate and less error correction [23], which are the main factors for the low latency optimal transmission [24]. However, high-quality Sị estimation is a difficult task, even for low-resolution videos. The WZ encoding and decoding are carried on either in the transform domain (TD) or the pixel domain (PD). Aaron et al. first time at Stanford proposed TD-based DVC framework [25]. In this framework, only the intra-frame statistical reliance is explored. It outperforms other codecs due to superior coding efficiency. Afterwards, the codec known as PRISM (Power-efficient, Robust, hIgh compression Syndrome based Multimedia coding) for TD was proposed by Puri et al. [26, 27]. Most of the adequate DVC codecs are found on the Stanford TD based framework. The DISCOVER [28] also complies with the Stanford framework [25].

Despite all the developments made by the DVC codecs [6, 10, 21, 29-31], consistent RD performance [32] is still an issue and, does not meet the superior performance of conventional codecs for all acute and non-uniform motion feature videos. This commonly happens due to the substandard quality of the WZ frame replica (known as Sị) which is estimated by interpolation or extrapolation [33] at the decoder. The superior coding efficiency and even the low bit-rate are achieved by making use of a highly correlated estimated replica of WZF [34]. However, the Sị generation process consumes a lot of time due to the computationally complex prediction (motion estimation and compensation) activities [35]. These prediction activities are highlighted as a major source of high computational complexity at the decoder and cause latency in the decoding process [13] even for low-resolution videos. Moreover, the feedback channel for error-resilience also imposes the delay and increases the decoder complexity [36] due to the iterative requests for more bits that are required for error-correction. This, in turn, increases computation complexity and decreases the life of the video sensor because the transmission requires more resources as compared to other operations [37].

III. Proposed DVC Model with Side Information Generation Scheme

In video processing, the vast amount of computation is involved in the estimation of the in-between frame due to prediction and estimation. Specifically, Sị estimation is the most challenging task in DVC decoding. The conventional interpolation methods require extensive computation resources and time; therefore, this extended computation complexity prolongs the decoding activity, especially for high-resolution videos.

Fig. 1 shows the proposed DVC Model for Sị generation with Phase-I and residual frame (Ʀ) calculation to reduce the transmission rate. The coding efficiency is associated with the transmission rate; therefore, to reduce the transmission rate, the Ʀ is calculated and encoded with WZ coding. The consecutive frames have the similarity and taking their difference will extract the motion part only which can be encoded in lesser bits than the actual WZ frame encoding, and WZ coding gives further lossy compression. The information will be encoded in fewer bits. The Ʀ can be calculated by (1).

Ʀ=W - □ (1)

In (1), the *W* is a current actual WZ frame, and *K* defines the previous key-frame.

Phase-I computes the pixel-wise phase modification without any extensive global optimisation and estimates pixel's motion by phase shifting of the individual pixels. In addition to this, the phase shift correction feature combines the phase information across all the levels of a multi-scale pyramid [38] in a very short time.

Avoiding the expensive global optimisation, which is a typical part of optical flow techniques, allows interpolating in-between frames in a fraction of time of the traditional interpolation methods. Therefore, in the DVC decoder, its deployment exclusively decreases Sị generation complexity and overall decoding time and complexity, even for the high-resolution videos.

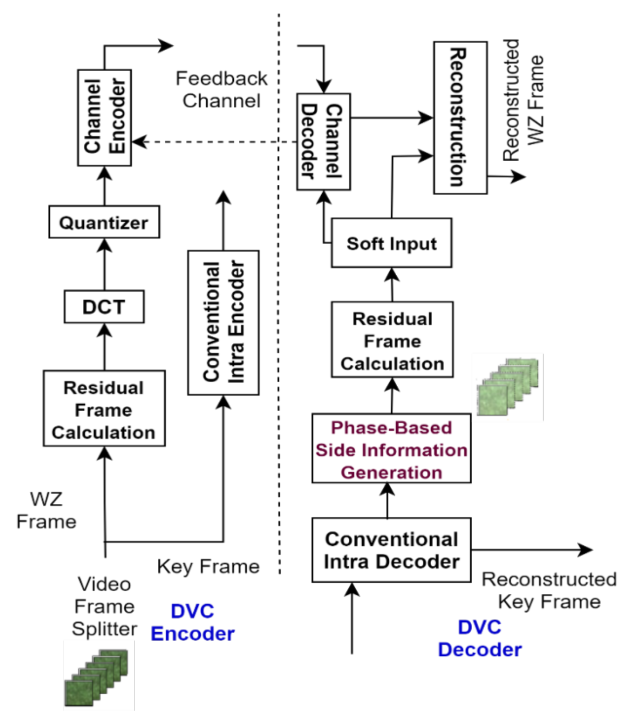

Fig. 1. Proposed DVC Model-Fast Side Information Generation for High-Resolution Videos.

The Phase-I algorithm summarises the execution steps of Phase-I. The input of Phase-I are two images and interpolation parameter α, and the process starts with steerable pyramid decompositions of both images and calculation of their amplitudes. The output of this algorithm is the interpolated image.

Phase-I Algorithm

Inputs: Two input images are: $I_1$and I_2

Interpolated parameter: α

Initialisation: Steerable pyramid decompositions: $P_1$and P_2

Amplitudes Calculation: $A_1$and A_2

Output: Output (interpolated image) : I_α

Step1: $(P_1, P_2) \leftarrow$ Decompose (I_1, I_2)

Step2: $(A_1, A_2) \leftarrow$ Amplitude (I_1, I_2)

Step3: $(\phi_1, \phi_2) \leftarrow$ Phase (P_1, P_2)

Step4: $\phi_{diff} \leftarrow$ Phase Difference (ϕ_1, ϕ_2)

Step5: $for\ all\ l = L - 1\ do$

Step6: $\tilde{\phi}_{diff}^{l} \leftarrow$ Shift Correction $(\tilde{\phi}_{diff}^{l+1})$

Step7: $end\ for$

Step8: $\hat{\phi}_{diff} \leftarrow$ Adjust Phase $(\phi_{diff},\ \tilde{\phi}_{diff})$

Step9: $\phi_\alpha \leftarrow$ Interpolate ($\phi_1, \hat{\phi}_{diff}$, α)

Step10: $A_\alpha \leftarrow$ Blend $(A_1, A_2$, α)

Step11: $P_\alpha \leftarrow$ Recombine (ϕ_α , A_α)

Step12: $I_\alpha \leftarrow$ Reconstruct (P_α)

In Fig. 2, the flowchart defines the basic steps for **Sį** interpolation with Phase-I. All mathematical notations are available in [38]. The flowchart presents the step by step process for estimation of the **Sį**. The Phase-I first decomposes the input images into the steerable pyramids, which is a linear multi-scale, multi-orientation image decomposition and calculates the amplitudes as well [38]. The Phase-I approach has a few intuitive parameters. The main parameters mainly used to control the number of orientations and levels corresponding to the different scales of the steerable pyramid. Better motion separation is achieved with a higher number of levels and orientations. The parameters setting used for generation of **Sį** is as follows; the number of orientations used is 8, and the number of levels L is determined such that the coarsest level has a minimum width of 10 pixels. For the limitation factor, we use τ = 0.2. The size of the coarsest level together with this choice of τ leads to a theoretical limit of motion which can be modelled reliably as 2% of the image width.

Depending on the size of GOP, both input images can either be intra-decoded key-frames or consists of the one intra-decoded key-frame and one previously estimated WZ frame, herein called **Sį**. In the next step, the phases are extracted with decomposed steerable pyramids. After the phase difference calculation, it is adjusted by the shift correction process. Now, for interpolating the next frame, the new phase is estimated with interpolation parameters, previous frame phase and the new calculated phase difference. Now, for the new **Sį** interpolation, a new amplitude is calculated by blending the interpolation parameter and extracted amplitudes of input frames. This new amplitude is combined with the new calculated phase to reconstruct the interpolated **Sį**. The focus of this work is only on the fast **Sį** generation for high-resolution videos; therefore, the full performance of codec will be presented in future work.

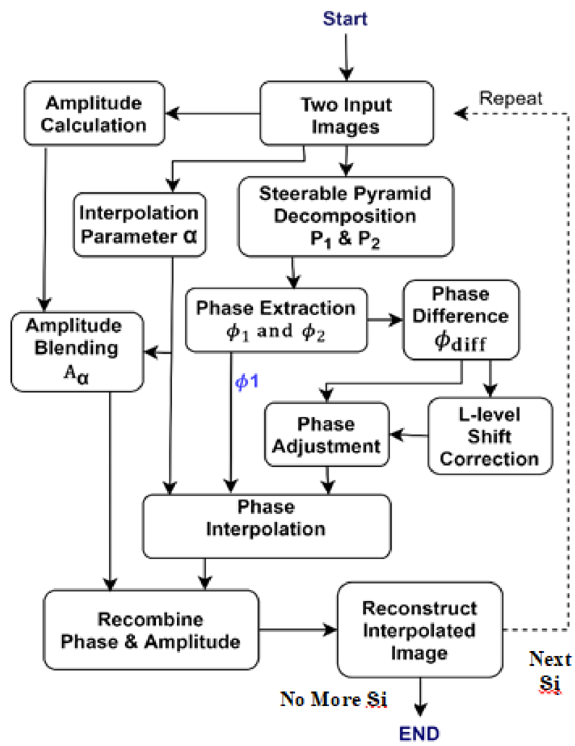

Fig. 2. Flowchart of Phase Interpolation (Phase-I) Algorithm Process for Side Information Generation.

IV. Result Evaluation and Discussion

The test clips WashDc in .cif (288x352) and .sif (480x640) formats, Mobile_Claneder in NTSC (486x720) and Old_Town Cross HD (720x1280) are taken for experiments [39]. The purpose of taking the different clips with different resolutions was to evaluate the performance of traditional and proposed Phase-I **Sį** generation approaches for different resolutions. The **Sį** quality and computational performance of its generation algorithm, are evaluated with quality metric PSNR and computational complexity metric execution time, respectively. To fairly evaluate the computational or coding complexity, the data cache size, memory access bandwidth, instruction cache size, storage complexity, execution time, parallelism and pipelining, all these dimensions should be measured [40]. However, practically it is difficult to measure all these dimensions [41]. Therefore, the coding time on a computing platform is usually considered for measuring the computational complexity as it is relatively easy to measure. It not only shows the computational complexity but also partially indicates the effects of other dimensions such as memory access, etc. in the coding process [41]. Consequently, this is a widely used metric for complexity measure. Therefore, for convenience, this is also used in this paper for coding complexity measures.

The number of calculations performed during a specific task defines the computational complexity. The total time of processor usage is directly affected by the number of calculations performed for a task; therefore, the computational complexity is always assessed and presented in processing time [42]. The performance of **Sį** generation algorithms is measured and compared with each other for the same video but with different high resolutions.

The performance is measured for two different GOP's of sizes 2 and 4. When GOP=2, the frames sequence will be the $I_1W_1I_2W_2I_3W_3I_4$, where $I_1I_2I_3I_4$ are intra-encoded and decoded key-frames, and $W_1W_2W_3$ the Wyner-Ziv frames whose estimated replicas are called **Sį**. When GOP=4, the frames sequence will be the $I_1W_1W_2W_3I_2$, where I_1I_2 are the key-frames, while W_1, W_2, W_3 are the Wyner-Ziv frames. In GOP=4, first, the $\mathbf{Sį}_2$ is estimated with I_1 and I_2, then $\mathbf{Sį}_1$ is estimated with $I_1$and $\mathbf{Sį}_2$ and, $\mathbf{Sį}_3$ estimated with $\mathbf{Sį}_2$ and I_2.

A. Computational Complexity Measure

The simulations are carried out on the Core(TM) i7-7820HQ, CPU 2.90GHz with 64-bit OS, and RAM 32 GB. The computation complexity of **Sį** algorithms; conventional interpolation called motion-compensated temporal interpolation (MCTI) and Phase-I for test sequences of 288x352 and 480x640 formats are presented in Fig. 3 and 4, respectively. The computation is measured for a single GOP of size 2 and 4 in different time slots of a test sequence. Time for single GOP of 2 and 4, is measured after every 30 frames.

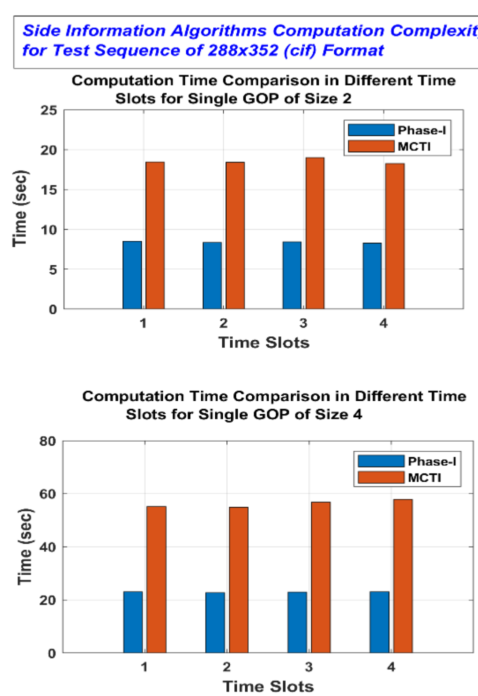

Fig. 3. Side Information Algorithm Computation Complexity for Test Sequence of 288x352 (cif) Format for GOP 2 and 4.

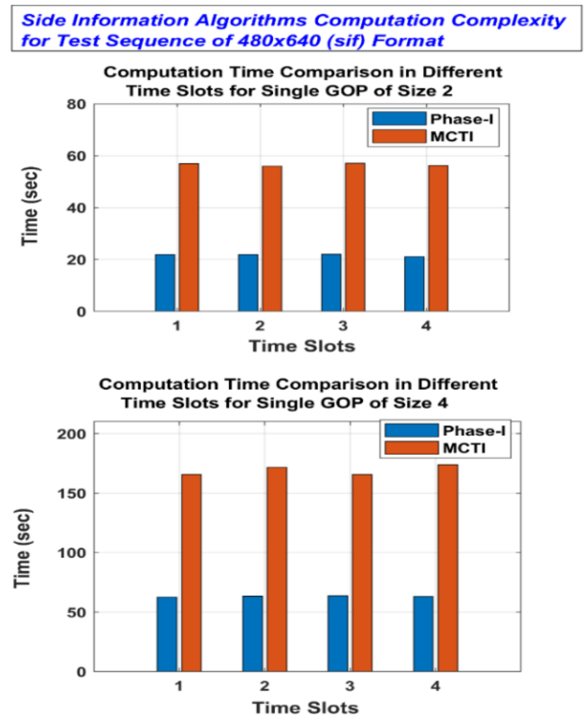

Fig. 4. Side Information Algorithm Computation Complexity for Test Sequence of 480x640 (sif) Format for GOP 2 and 4.

For the 288x352 format test sequence, the average **Sį** estimation time taken by Phase-I is 8.38 sec, and MCTI is 18.54 sec for GOP 2. The Phase-I took an average of 22.91 sec, and MCTI an average of 56.19 sec for single GOP of size 4. Simulation results show that Phase-I is an average of 221% and 245% faster from the MCTI for GOP 2 and GOP 4, respectively. For the 480x640 format test sequence, the average **Sį** estimation time taken by Phase-I is 21.74 sec, and MCTI is 56.54 sec for GOP 2. The Phase-I took an average of 63.155 sec, and MCTI an average of 169.23 sec for single GOP of size 4. Simulation results show that Phase-I is an average of 260% and 268% faster from the MCTI for GOP 2 and GOP 4, respectively.

Computationally, the Phase-I is much faster than MCTI for all resolution videos and delivers optimum performance for different GOP sizes. This reduces the overall decoding complexity and hence leads to the faster decoding for high resolution of videos.

B. PSNR Performance and Discussion

The PSNR is conceived as one of the image quality measuring metric. It reflects the quality of estimation frame relative to the actual frame. Fig. 5 presents the PSNR performance as a function of frame numbers in a given sequence of frames. The comparison is made among the MCTI method and Phase-I for the GOP size of 2 (only PSNR of estimated **Sį**) and PSNR of relevant intra-decoded frames for both .cif and .sif formats.

The simulation results implemented for .cif format points out the average PSNR of 35.5dB and 31.2 dB for MCTI and Phase-I, respectively. The implementation results of .sif format showed the average the PSNR 35 dB and 31 dB for MCTI and Phase-I, respectively. The proposed approach performance is approximately 4-4.3 dB poorer than that of MCTI for both formats. Although, the Phase-I lag behind the MCTI by 4.2 dB but deliver consistent performance throughout the sequence. The proposed method's efficiency falls by 11.26% of MCTI. However, the 30dB PSNR is considered as the minimum acceptable quality for a human vision [43].

Fig. 6 presents the PSNR performance graph for the MCTI and Phase-I for a GOP size of 4 (only PSNR of three estimated Sį of each GOP) and PSNR of relevant intra-decoded frames for both .cif and .sif formats. The simulation results implemented for .cif format pointed out the average PSNR of 33.24 dB and 27.95 dB for MCTI and Phase-I, respectively. The implementation results of .sif format presented the average PSNR 32.34 dB and 30.8 dB for MCTI and Phase-I, respectively. The MCTI achieved average 4.29 dB better PSNR from Phase-I but inconsistent performance for each GOP. While MCTI performance degraded for .sif format, whereas Phase-I performance improved for .sif format. Therefore, the Phase-I has great potential to deliver better for high-resolution videos with a large GOP size.

The computational complexity and quality performance evaluation of both Sį algorithms are presented in Table I. The computational complexity and quality evaluation are in the form of average time and average peak-to-signal ratio (PSNR) of Sį of the GOP respectively.

Simulation tests were also carried out on several other videos of different formats and motions, and few of them are also listed in Table I. Simulation conditions are frequently changed to analyse the visual quality and computational complexity of the proposed approach. The Phase-I based Sį visual quality is dependent on the quality of intra-decoded frames. With high visual quality intra-decoded frames, the Phase-I algorithm generates better Sį and vice versa. On the other hand, with one high quality and another low-quality intra-decoded frame, the Sį quality degraded according to the low one.

In the current scenario of GOP 4, the reference frames are changed according to the mentioned methodology, and visual quality of every estimated Sį frame varies accordingly. However, an attempt is made to generate more than one Sį frames by keeping the same reference frames, a bit low but almost consistent visual quality Sį's are generated in minimal time. In that approach, the computation time was 2-2.5 times less than the currently implemented strategy at the cost of a small degradation in the visual quality of all Sį's. This will open the door for implementation of low-delay or real-time Sį generation with large GOP size. However, the study is required to analyse its effect on transmission rate in the channel decoding step because further correction in Sį should be needed to achieve consistent high visual quality in video.

The visual performance slightly depends on some parameters of Phase-I algorithm like decomposition level of steerable pyramids, phase extraction step, phase shift correction step and amplitude calculation step when only one Sį is computed. However, the computation time rarely changed with the change of these parameters.

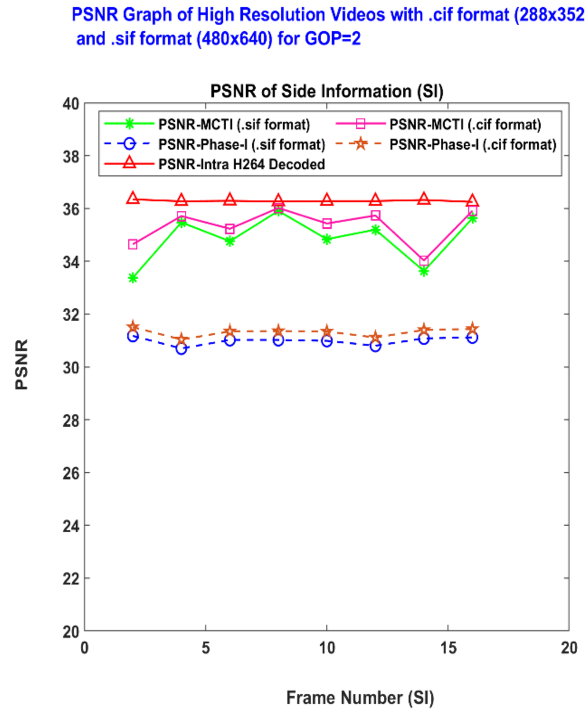

Fig. 5. PSNR Performance Measure of Phase-I and MCTI for .cif(288x352) and .sif(480x640) for GOP=2.

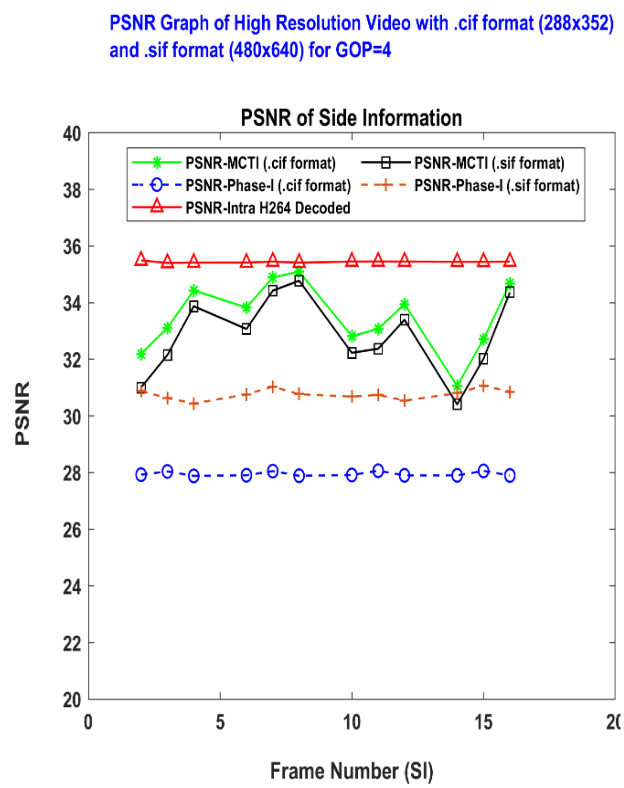

Fig. 6. PSNR Performance Measure of Phase-I and MCTI for .cif(288x352) and .sif(480x640) for GOP=4.

TABLE I. COMPUTATIONAL COMPLEXITY (IN AVERAGE TIME) AND QUALITY (IN AVERAGE PSNR) FOR SINGLE GOP OF SIZE 2 AND 4

Test Sequence Formats	Computational Complexity (Average Time (sec))				Quality Analysis-Average PSNR (dB)			
	GOP= 2		GOP=4		GOP=2		GOP=4	
	MCTI	Phase-I	MCTI	Phase-I	MCTI	Phase-I	MCTI	Phase-I
WashDc.cif (288x352)	18.54	8.38	56.19	22.91	34.64	31.50	33.24	31.01
WashDc.cif (480x640)	56.54	21.74	169.23	63.16	33.46	31.17	32.34	30.65
Mobile_Claneder.NTSC (486x720)	64.79	25.11	187.45	71.54	35.15	30.98	34.78	30.10
Old_Town Cross (720x1280)	147.31	52.17	386.30	139.13	34.90	31.20	34.43	30.34

V. FUTURE DIRECTION

In current Phase-I algorithm, the visual quality changes with reference frames (frames that are used for Sį estimation) quality. Especially the performance of algorithm degrades when one of the reference frames is of low quality. Therefore, the focus can be put to design this algorithm in a way that it changes performance with respect to high-quality reference frames to get the Sį with consistent visual quality in either condition. Getting a consistent high-quality Sį will also assist in reducing the number of bits (bit rate) which are required for Sį correction in the channel decoding step. It reduces the transmission rate efficiently for both low and high-resolution video.

In large GOP size, the visual quality almost remains the same for all estimated Sį when the same reference frames are used to estimate all the intermediate Sį frames. This method of generating the intermediate Sį frames makes the Phase-I computationally very effective, but it lack-behind in visual performance. Visual quality remains a bit low from other adopted approach. Therefore, the algorithm should be designed in a way that it estimates more than one high-quality intermediate frames at once in a very short time. If this less computational complexity method estimates the consistently high-quality Sį, then it will be effective to achieve the low-delay or real-time DVC decoding for both low and high-resolution videos. Moreover, it also reduces the transmission rate efficiently for both low and high-resolution videos with large GOP size.

The visual performance slightly depends on some parameters of Phase-I algorithm like decomposition level of steerable pyramids, phase extraction step, phase shift correction step and amplitude calculation step when only one Sį is computed. But these parameters somehow put their effect when two reference frames are far away from each other and the computation time rarely affected by changing these parameters. Designing an adaptive Phase-I will be a productive step for auto-selection of these parameters, to generate a consistent high-quality Sį in small computational time and transmission rate for video applications can be controlled with it. Along with the high-quality Sį estimation in small time, the proposed residual frame calculation at the encoder further reduces the transmission rate and improves the codec coding efficiency.

VI. CONCLUSION

The DVC decoder faces the computational complexity while estimating the replica of the WZ frame known as side information (Sį) due to the involvement of the prediction process. The traditional Sį generation algorithms raise a high computation complexity in decoding process because of the complex and composite prediction process and even took a long time for low-resolution video. However, the emergence of high-resolution video sensor demands high-speed DVC decoder with faster Sį generation algorithms. This research work proposed the DVC model with the Phase interpolation (Phase-I) algorithm for Sį estimation. It computes the pixel-wise phase modification without any explicit correspondence estimation and pixel's motion by phase shifting of the individual pixels. In addition to this, the phase shift correction feature combines the phase information across the levels of a multi-scale pyramid in very little time. Therefore, in the DVC decoder, its deployment exclusively decreases Sį generation complexity and overall decoding time and complexity, even for the high-resolution videos. It works efficiently and even better for high-resolution videos with large GOP. It exhibits low computation complexity for both low and high-resolution videos. Moreover, it delivers significant efficiency in the computation for different GOP sizes at the cost of some degradation in the quality of estimated Sį. However, for high-resolution video with a GOP size of 4, the results were acknowledgeable because the performance of the traditional algorithm drops out rapidly, and where on the other hand, Phase-I remains stable.

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Level of Depression in Tuberculosis Patients of Los Olivos Health Centers

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***Abstract*—Tuberculosis is a contagious infectious disease, caused by Mycobacterium Tuberculosis, transmitted through its release into the air when a sick person coughs, sneezes or talks, so it can be inhaled by another person and infect it, it is necessary for patients to adopt family, work and social distancing to avoid infections, causing a risk of developing different levels of depression, which is detrimental due to its negative influence on decision-making. The frequency of depression in society is high, as is the predisposition of patients diagnosed with Tuberculosis due to the sudden change in their lifestyle, which is why it was proposed to determine the level of depression in tuberculosis patients at health centers from Los Olivos district, this study will also allow to know the most frequent physical and psychological reactions, in addition to the most predominant sex. To obtain the information, the corresponding permits were obtained and the Patient Health Questionnaire 9 (PHQ-9), an international and nationally validated standardized instrument, was applied; the data was processed in the statistical software SPSS 24.0, and the graphics were subsequently extracted; where the following obtained results were reflected: 100% of the participants had some level of depression, the most prevalent being the level of moderate depression with 35.56%, being more present in the female population with 21.11% , it was also shown that 48.9% of patients almost always have little interest or pleasure in doing things.**

***Keywords*—Tuberculosis; depression; patient health questionnaire 9; health centers; tuberculosis lifestyle**

I. Introduction

Depression is a common and debilitating mental disorder (1), characterized by a feeling of sadness, loss of interest, guilt, low self-esteem, sleep or appetite disturbances, fatigue and lack of concentration (2), according to a report by the WHO and PAHO, a total of 322 million people who suffer from it, of which 1,443,513 belong to Peru and 9.7% of them have some non-psychiatric illness (3). Affected people decrease the ability to carry out their daily activities and have low academic performance, affecting economically and socially, in addition has a negative influence on adherence to anti-tuberculosis treatment (4) causing treatment abandonment which generates an increase in resistant multidrug TBC rate (5).

Tuberculosis is an old disease, however, it continues to be a public health problem worldwide, causing around 1.7 million deaths and 9 million new cases each year (6,7), and has also been shown to be fatal for patients with HIV-AIDS (8), it is known that the bacterium Mycobacterium tuberculosis, according to the WHO, this bacterium would be present in at least a third of the world population (9,10), can lodge in different organs, however, the cases in which lodges in the lungs (11), these smear-positive patients are highly infectious, since they generate coughs, chants, screams, sneezes, nuclei of drops containing the bacteria (12) that can be inhaled by Healthy people, individual and environmental factors intervene in this process, such as: the person's lifestyle and the ventilation of the environment (13).

Patients diagnosed with Tuberculosis generally belong to poorer social strata (14), who have to make changes in their lifestyle, which can have psychological repercussions, the main one being depression, generally associated with social distancing (4,15)**,** which is closely related to the type of tuberculosis and its location.

Currently, many countries have a high burden of tuberculosis and are not on track to reach the goals set for 2020, this set seeks to end it, this as evidenced in the annual report of the World Health Organization, where they report that globally, the reduction targets set for infection and deaths are considerably lower (7).

The Instituto Nacional de Estadísticas e Informática, pointed out that 3.4% of people 15 years of age and older know or have heard of tuberculosis and recognize the forms of transmission, according to distribution by sex, the knowledge of transmission of the disease was higher in women (4.1%) than in men (2.9%), the majority of those who know about the form of transmission resided in metropolitan Lima, continuing, in lower percentages, the population of the coast and jungle , while in the Highland region, they showed that they did not know about different diseases, so better information is needed from the population (16).

In (4), the association of depression with the absence of patients in their treatment was evaluated, using the PHQ-9 depression scale as an instrument, where it was evidenced that depression was present in 76% of the population, In addition, a statistically significant association ($p>0.05$) between levels of adherence and depression was determined, according to the instruments used.

In (17), the level of depression was evaluated in patients diagnosed with Tuberculosis, as a result they found that 54.5%

of the study population had some level of depression. 32.7% of the patients had mild depression and 7.3% had severe-moderate depression according to what was evaluated by the PHQ-9 depression scale, they also found a significant relationship according to sociodemographic data.

In (18), they evaluated the burden and presentation of depression in individuals newly diagnosed with Tuberculosis, obtaining as a result that the prevalence of depression was 54.0%, where it was highlighted that little interest or pleasure in doing things (73.0%) was the most common depressive symptom, they also determined that the duration and severity of Tuberculosis symptoms were important factors independently associated with depression.

In (19), the prevalence of depression in tuberculosis patients was 61.1%; 38.9% of patients had no depression, 36.6% had mild depression, and 24.5% had moderate depression. Women were more affected than men (38.5% vs. 22.6%). Major depression was found in 41.5% of patients, with 27.9% of women and 13.6% of men.

According to the bibliographic search carried out for the preparation of this research, the scarcity of related studies was evidenced, as well as the age of the existing ones, therefore the main objective of the research work is to determine the level of depression in patients diagnosed with Tuberculosis who receive their treatment at the health centers of the Los Olivos district, Lima-Peru, it will also determine the most predominant factors of depression, the reactions physical and psychological, the importance of this research lies in the frequency of depression in society, in its consequences and in the predisposition to develop it in patients diagnosed with Tuberculosis due to the change in lifestyle.

The data will be obtained through the PHQ-9 questionnaire, which allows detecting Depression, from Mild to Severe, this has proven to be an efficient diagnostic instrument, in addition to being used nationally and internationally (20), however, it is not widely used in this population. Subsequently, the data will be processed using the SPSS Software, extracting the results from it to be interpreted.

The following research work is structured as follows: In Section II, the methodology for obtaining data and its processing will be presented, in addition to presenting the flow diagrams of the processes that were carried out to obtain the meaning of each image. In Section III, the results of the research work will be shown using bar graphs according to percentages. In Section IV, the discussions of the research work will be presented. Finally, in Section V, the conclusions on the research work as well as some recommendations on depression in tuberculosis patients will be presented.

II. Methodology

This section shows the procedures performed that consist of data acquisition and processing. As the reader can see the Fig. 1.

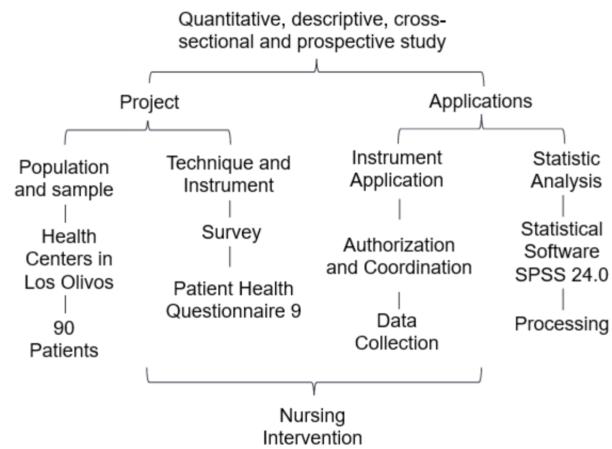

Fig. 1. Flow chart for Obtaining Results.

A. Population and Sample

For the research, the selected population were patients receiving treatment in the area of the national health strategy for the prevention and control of Tuberculosis in the health centers of Los Olivos district, Lima-Peru; the total of our sample was 90 patients who voluntarily participated in the study, being informed about the study and having an informed consent as evidence.

B. Technique and Instrument

As a data collection technique, the survey was used, which allowed to establish contact with patients; the instrument that was applied was the Patient Health Questionnaire 9 (PHQ-9), validated and submitted to the judgment of experts nationally and internationally for the screening for depression, through 9 items, in which patients rate their symptoms or signs on a Likert scale, the sum is distributed in: Minimum or none: 0-4, Mild: 5-9, Moderate: 10-14, Moderately severe: 15-19, Severe: 20-27 (21–24).

C. Application of Instrument

After the approval of the ethics committee of the Universidad de Ciencias y Humanidades, permission for the application of the instrument was requested from DIRIS (Direcciones de Redes Integradas) Lima - North.

Once the permission was obtained, data collection began in October 2019, mainly on Tuesdays and Wednesdays, on the recommendation of the managers of the area.

The instrument was applied individually and lasted approximately 15 minutes.

D. Statistical Analysis

The data was entered into a matrix table prepared in the statistical software SPSS 24.0, this process was carried out carefully to avoid errors and missing values at the time of analysis.

Finally, graphs and tables were extracted that will be described and then these will allow the discussion of the respective study.

E. Nursing Intervention

The importance of the intervention of Nursing professionals lies in the interaction maintained during the collection of information, the trust and support provided during the completion of the survey to obtain real data as the reader can see in the Fig. 2. When the data is socialized, the nursing professionals who are in charge of the Tuberculosis control and prevention program will be able to approach and manage interventions to prevent depression in patients.

Fig. 2. Data Collection Procedure using the Survey.

III. Results

The study included 90 patients who were receiving treatment for tuberculosis at the olive health centers.

The instrument allowed to synthesize as the reader can see in Fig. 3 the information collected, it shows that the level of moderate depression prevailed in patients with 35.56%, followed by severe depression with 26.67%, while 24.44% maintained a mild level of depression and 13.33% had a moderately severe level of depression, with no participants found without a level of depression.

Fig. 4 shows that of the total population, 60% belonged to the male, while 40% to the female. The predominant level of depression in the female was moderate with 21.11%, followed by the severe level with 7.78%, continuing with the moderately severe level with 6.67% and with a low level with 4.44 %.

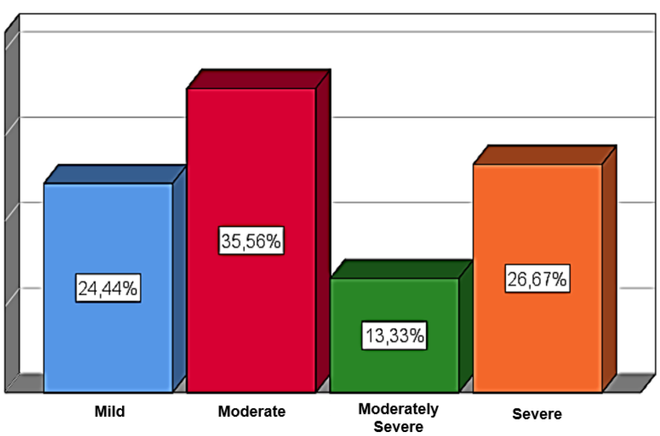

Fig. 3. Level of Depression in Patients with Tuberculosis.

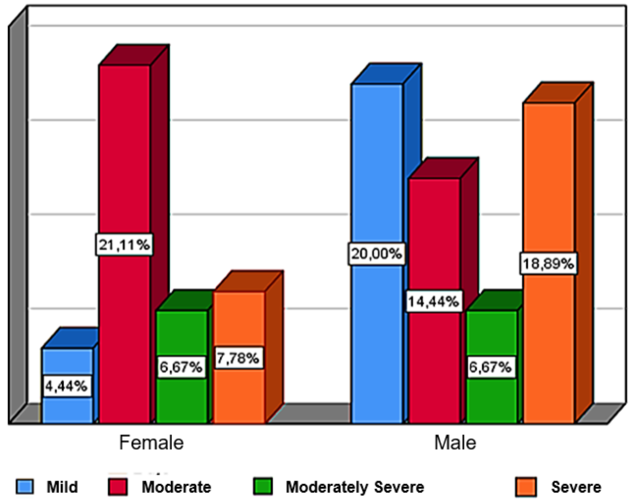

Fig. 4. Level of Depression in Patients with Tuberculosis According to Gender.

Regarding the male, the level of low depression predominated with 20.00%, followed by severe depression with 18.89%, while moderate depression is present in 14.44% of the population and a 6.67% present a moderately severe level.

The instrument also allowed to synthesize the signs and symptoms most present in patients with Tuberculosis. Fig. 5 shows that almost every day, 48.9% of participants show little interest or pleasure in doing things, while more than half of the days, 37.8% have felt sad and depressed, in addition to several days, 70% have little or excessive appetite, 62.2% have had trouble sleeping, staying awake or sleeping too much, 47.8% feel tired or have little energy, 44.4% move or talk so slowly that other people may notice or are so restless and uneasy that they go from one place to another more than usual, the 42.2% have had trouble concentrating on activities such as reading the newspaper or watching television, finally 38.9% have never felt bad about themselves or that they are a failure or that they failed family and themselves, 54.4 % has never thought that would be better dead or wished to harm itself in any way to.

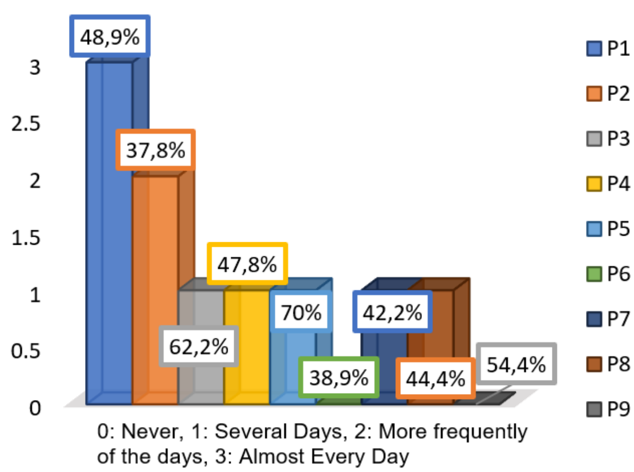

Fig. 5. Signs and Symptoms of the Level of Depression in Patients with Tuberculosis.

The consideration of the results of our study lies in the evidence of the vulnerability of patients due to Tuberculosis, since it generates drastic changes in their lifestyle, and they tend to develop signs and symptoms that expose them to depression, which influences negatively often in other diseases (3), which can trigger in different situations, ranging from problems such as lack of adherence to treatment to suicide, which has been demonstrated in different studies such as depression and adherence in people affected with tuberculosis of the authors Llanos-Tejada and Ponce-Chang, our study is socialized, it will allow the corresponding professionals to have the opportunity to elaborate and apply plans for the prevention of the development of depression, since evidently all patients have some level of depression.

IV. Discussion

The present research work had 90 participants who had a medical diagnosis of Tuberculosis, who were receiving treatment at a health center in Los Olivos district.

The study confirms that patients with Tuberculosis tend to have different degrees or levels of depression, since as a result it was found that 100% of the participants have some level of depression according to the Patient Health Questionnaire 9, which is higher than the results, obtained in Peru from Bonilla (17), who reported that 54.5% of the study population had some level of depression, and also higher than that reported in Ethiopia by the Mayston study (18), which the prevalence of probable depression was 54.0%.

The level of moderate depression prevailed in patients with 35.56%, which disagrees with the results of a study carried out in Cameroon (19), where 38.9% of patients did not have depression, 36.6% had mild depression and 24.5% had moderate depression.

The level of moderate depression prevailed in patients with 35.56%, which disagrees with the results of a study carried out in Cameroon (19), where 38.9% of patients did not have depression, 97 (36.6%) had mild depression and 65 (24.5%) had moderate depression.

The predominant sex in our research is male with 60%, which coincides with the report of the Ministerio de Salud (4), where it indicates that Tuberculosis is more frequent in the male population.

Severe depression was present in 26.67% of the participants, of which 18.89% belonged to the male sex, while 7.76% to the female sex, differing with a study (19), where it was found Severe depression in 27.9% of female participants and 13.6% of male participants, in another study carried out in Pakistan (5), found that the odds of depression in women were higher than in men, which does not coincide with our study.

The instrument used allowed us to show that: almost every day, 48.9% of patients show little interest or pleasure in doing things, which is similar to the study carried out by Ambaw (18), furthermore, this symptom was related with the results of a study (4), where patients with tuberculosis and depression tend to abandon or miss their treatment for tuberculosis.

Due to the scarcity and age of studies reflecting the level of depression and its predominant symptoms and signs in patients with tuberculosis, a broader discussion could not be conducted.

V. Conclusions

The research was carried out using a standardized questionnaire that evaluates the level of depression (PHQ-9), consisting of 9 items, this was applied to patients with tuberculosis from the Los Olivos Lima health centers - Peru, there were a total of 90 patients who participated in the study, those who met the inclusion criteria and voluntarily wanted to participate in the study.

In addition, the health centers provided us with accessibility for the acquisition of the information collected through the instrument applied to patients with tuberculosis, for which it was necessary to present the authorization of the DIRIS Lima Norte.

Patients receiving treatment for Tuberculosis in the different Health Centers in Los Olivos present some level of depression, with the level of moderate depression prevailing in 35.56% of the population.

Moderate depression was mostly present in female patients, however, in male patients it was evident that severe depression was significant.

According to the applied instrument, the signs and symptoms of depression most present in the Tuberculosis patients evaluated were: Little interest or pleasure in doing things, showing a risk of abandoning treatment, another relevant sign was feeling sad and depressed.

It is important to highlight and encourage the use of the PHQ9 instrument, as it is an easy and quick questionnaire to administer and analyze, in addition to being valid for the timely diagnosis of depression in patients with Tuberculosis.

Finally, we consider that depression must be evaluated in all tuberculosis treatment centers, health professionals must provide adequate treatment and psychological support.

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How Entrepreneurs Utilize Accelerators: A Demographic Factor Analysis in Turkey using Regression

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***Abstract*—This study examines entrepreneurs participating into eight accelerator programs located in Istanbul, Turkey. Business accelerators are a new kind of incubation program built in particular to help technology entrepreneurs and assist them reach to the next level. In total eight accelerator programs are researched in this study. A survey is developed for this study and applied to entrepreneurs attending these eight accelerator programs. In this survey, the effectiveness of these programs are measured according to the demographics of entrepreneurs. The aim of this research is to analyze how entrepreneurs use the services given by the accelerator program. In relation to entrepreneurs' age, gender, work experience, educational status and family background, several hypotheses have been identified for assessing the value of supports given in these accelerator programs. The data of this research have been examined via SPSS using Mann-Whitney and Kruskal-Wallis methods. According to the results of these tests, a regression model called Generalized Linear Mixed Model (GLMM) has been developed. This study adds to the literature by examining accelerator supports and facilities so that accelerators can set apart their programs in line with the requests of the entrepreneurs.**

***Keywords*—Accelerators; e-business; startups; regression**

I. Introduction

The development of internet started a new era for entrepreneurs especially for the ones in the technology field. Cloud technology and open source software have made it possible for entrepreneurs to develop a new business with less capital. Therefore, the expenses of founding a new technology business dropped significantly compared to the initial phases of internet and it is very easy to found an internet business [1]. However, in the 90s, the expenses of founding a new internet venture was high and involved more risks [2], [3]. For this reason, business incubators were established to help entrepreneurs and lower their risks. Incubators connected technology, talent, know-how and capital together in order to expedite the commercialization of technology [4]. They mainly provided office space and administrative assistance to innovative companies and also, gathered them together under the same roof for interaction [4]- [6]. Nonetheless, incubators lack an exit policy which caused problems for investors [7]. Therefore, in mid 2000s, a new a new kind of program called "accelerator" was born to support new businesses in technology sector which are also called startups.

Accelerators accelerate new businesses especially startups by becoming a bridge between them and the broader entrepreneurial environment [8] and offer them specific services for a certain extent, usually up to 6 months [9]. Among these services are office space, mentoring, training, networking, meeting with investors, advertising and access to different financing options [8], [10]- [14]. Startups use an open application system online to apply to these programs and go through a selection process to be accepted. Accelerators also help startups find seed/early-stage funding opportunities from investors. This is one of the major differences between an accelerator and an incubator. The incubators only provide tools, space and mentoring for startups [15] whereas an accelerator help the startups overcome the liability of newness and attract investors [16].

A predefined and firm description of an accelerator, plainly explaining the accelerator model from other incubation models is needed to choose the right programs for this study. Therefore, Miller and Bound's [12] definition of accelerators is used since it is widely accepted by many scholars [1], [10], [17], [18]. Accelerators have six main characteristics according to Miller and Bound [12]. These are; an application process open to all, time limited support, cohorts or classes of startups, seed investment in exchange for equity, a focus on small teams rather than individuals and finally, a graduation with a demo day [1], [17]. This study chooses to analyze accelerator programs located in Turkey due to Turkey is an emerging country according to Morgan Stanley Capital International emerging market index [19] and it is geographically considered as a bridge between Europe and Asia. Also, it has a population of 83 million according to World Population Review making it among the 20 largest countries of the world [20] and this population has very high internet and mobile phone penetration rates. According to Statista, there are 56 million internet users and 77.8 billion mobile phone users [21], [22]. All of these factors make Turkey a desired location for technology entrepreneurs. 28 accelerator programs exist in Turkey as of April 2018 and only 10 of these have the features of an accelerator program. All of these 10 programs are located in Istanbul. However, 8 of these programs agreed to participate on the research out of the 10, and this research implements a study on the entrepreneurs who have been through or are currently present in these eight accelerators. These are Starter's Hub, Pilot, ITU

Seed, Kworks, SuCool, Albaraka Garaj, IOT Telco Labs and Lonca.

The aim of this research is to perform a statistical analysis on entrepreneurs in the eight accelerator programs stated above. More and more accelerator programs are opening up every year around the world and although it is known that success stories have emerged from accelerators, it has not been researched before thoroughly how effective their supports are for entrepreneurs. It will be analyzed how entrepreneurs use the services given by the accelerator program. By means of this research, accelerators will be able to differentiate their programs and the supports they provide according to entrepreneurs' needs and will be able to deliver them more beneficial programs. If the accelerator programs know which entrepreneurs need more support, they can direct them and contribute to their development in order to help startups grow more. In this way, entrepreneurs can grow their companies and increase their chances of success. This enlarges the entrepreneurship ecosystem and makes a positive contribution to a country's economy and employment rates.

Literature studies on accelerator programs are also very few and even insufficient [10], [23], [24]). According to Cohen and Hochberg [10], there are several reasons for this. The first of these reasons is that some programs that contain the word accelerator are not actually an accelerator but are essentially an incubator center, so researchers have to look for the actual accelerator program to work. This problem was also encountered during this study. Another reason is that the accelerator programs are quite new so do not have sufficient data. Another reason for Albort-Morant and Oghazi [23] is that start-up companies participating in accelerators are early stage companies and often do not have enough data to work. Finally, not all companies taking part in the accelerator program are always able to continue their lives and some of them are closed in the first 5 years. This makes it difficult for researchers to collect data.

In the next section, hypotheses of this study will be indicated. Section 3 describes the methodology and hypotheses used in this study. Section 4 clarifies the results and explains the findings. Finally, Section 5 discusses the conclusions, limitations of this study and future work opportunities.

II. Methods and Hypotheses Development

This research concentrates on 8 accelerator programs. These programs differ from each other in terms of how they are supported. ITU Seed, Kworks and SuCool are programs supported by government organizations in addition to universities. ITU Seed is within the structure of Istanbul Technical University, Kworks is within the organization of Koc University and SuCool is within the structure of Sabanci University. Pilot, Albaraka Garaj and Lonca are programs supported by corporations. Pilot is founded by Turkish Telecom, Albaraka Garaj is founded by Albaraka Turk Bank and Lonca is founded by Kuveyt Turk Bank. Starter's Hub and IOT Telco Labs are hybrid programs. They are supported by a few different organizations. Starter's Hub is supported by Gedik Invesment and Murat Vargi Holding. IOT Telco Labs is supported by Nexus Ventures and Istanbul Startup Angels investor network. Corporations prefer to support accelerators in order to reach new ideas and innovations which will help them grow and renew themselves [25]. In this way, they can also get connected with entrepreneurs and increase their talent pool.

The aim of this study is analyzing which demographics of entrepreneurs raise or reduce the need for support from accelerator programs and the benefits they obtain from these programs. The demographics of entrepreneurs that are taken into consideration in this study are age, gender, professional work experience, educational status, and to have an entrepreneur in the family or social circle. The accelerator supports are compared according to the entrepreneur demographics. As a result of this study, accelerators can alter their programs in order to fulfill entrepreneurs' needs and help them grow their businesses.

Previous studies made with entrepreneurs examine if the capacity of the company and human capital change the necessity to obtain support from the incubators or not [4], [26]. Rather than incubators and the human resources, this research concentrates on entrepreneurs currently present on accelerator programs and looks at entrepreneurs' demographics to analyze which supports and services entrepreneurs need the most in terms of their gender, age, educational status, work experience and family background. Moreover, majority of researches related to incubation and accelerator programs lack a consistent theory [27] and are largely descriptive in nature [10], [12]. Thus, in this study, an experimental framework is used and the below proposals are analyzed. This study is built upon the previous studies of [28], [29] and therefore, uses the same survey data.

A. Research Design and Hypotheses

In this study, the propositions are designed based on the model as shown in Fig. 1. In this model, it will be investigated whether the characteristics of the entrepreneur affect the utilization level of the services provided in the accelerator program and the level of receiving benefit for the development of the company.

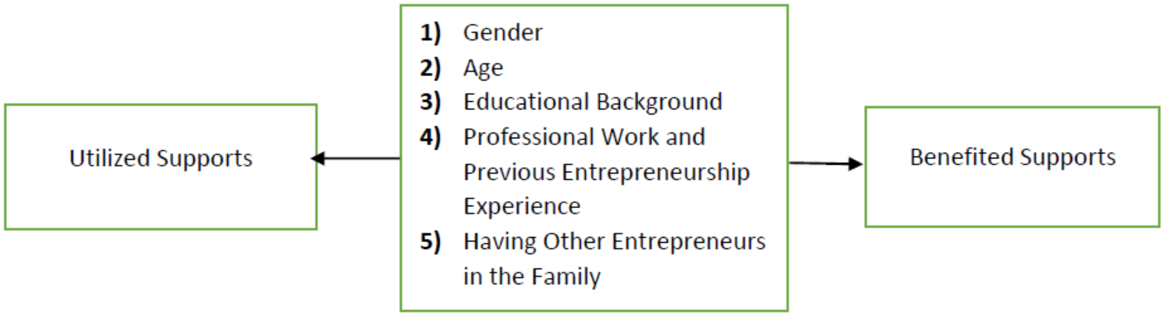

Fig. 1. Research Design.

There is historically inherited male dominance and this causes a huge gender gap on entrepreneurship. Berglann et al. [30] state that only 25% of entrepreneurs are female. Moreover, the degree of female businesspersons establishing a technology business is only 5%, as stated by a survey implemented by Women who Tech in 2012 [31]. As indicated by authors Carrasco and Cuevas [32], Hechavarria and Reynolds [33], Thach and Kidwell [34], the amount of female entrepreneurs is growing every year. Nevertheless, in comparison to other sectors the rate of female entrepreneurs in technology is much lower. The reason of this is that women are underrepresented in science, technology, engineering, and mathematics (STEM) jobs [35], [36], [37], [38]. Stoet and Geary [39] made a study researching the gender equality paradox in STEM. According to their research, countries with lower level of gender equality had relatively more women among STEM graduates than did more gender equal countries. This is interesting to point out because gender-equal countries are those that give women more educational and empowerment opportunities, and mostly promote women's engagement in STEM fields [40]. Another reason why there are less women entrepreneurs is that the motives for starting a business for women and men are very different. Women start businesses [41] to earn their freedom and get fulfillment in their jobs [42], whereas men start businesses to have a better job and receive more earnings. Considering men and women are physiologically different than each other, they may need different supports to grow their businesses because gender-related psychological traits related to managerial differences do exist [43].

Ha1: The supports that men and women use the most in accelerator programs are different. They utilize different supports.

Ha2: The supports from accelerator programs that men and women benefit the most are different.

Entrepreneurs' ages have dropped in the last few years. Studies which observe the effects of age on entrepreneurship by analyzing young entrepreneurs already exist. These researches were performed by Levesque and Minniti [44], Montes Rojas and Siga [45] and Thomas [46]. Young people are eager to take more risks than older people and therefore, they have a tendency to be entrepreneurs [44]. Young people are more courageous and energetic and thus, more willing to take on the risk of founding a new business according to Blanchflower and Meyer [47]. It gets more problematic for individuals to found a new business as they age because the things they need to give up and their responsibilities grow concurrently with their ages. Unless they are unemployed or find themselves a prospect to become an entrepreneur, they are less likely to found a new venture [25].

Hb1: The need for support from the accelerator program drops as the entrepreneur ages.

Hb2: The benefit it gets from the supports of accelerator program declines as the entrepreneur ages.

Entrepreneurs can gain some of the skills they need such as business management, leadership, technical and behavioral skills through formal education. Nonetheless, there are contradictory researches about the consequences of education on entrepreneurial approaches. According to Shapero [48], Fallows [49], Ronstadt [50], Laukkanen [51], Peterman and Kennedy [52] and Wu and Wu [53], the higher education an individual has, the less likely this individual will launch a new venture. Authors state a few reasons for this. The first one is that an individual with a degree can find a better job as an employee. The second one is that formal education increases the rate of avoiding risks and decreases curiosity as well as the tolerance of dealing with ambiguity. Moreover, there are some schools which specifically encourage their students to work in large corporations instead of small businesses. Alternatively, some other studies propose that higher education has a positive impact on entrepreneurship. These studies are performed by Robinson and Sexton [54], Davidsson and Honig [55], Ilhan Ertuna and Gurel [56]. This means an individual with higher education will more likely to found a new business.

Hc1: The need for support from the accelerator program declines as the level of education of the entrepreneur rises.

Hc2: The benefit it receives from the supports of accelerator program declines as the level of education of the entrepreneur rises.

Theoretical education cannot give the ability to make better decisions, only experience can. Organizational skills that come with experience can only be gained by working as an employee in a corporation [25]. In addition, it is difficult to learn how to run a company without working as a manager or without observing your managers. According to Mintzberg [57], the best way to learn how to run a company is through acquiring direct experience. Else, an individual cannot realize all of the aspects of running a business. Therefore, a person without any managerial knowledge should get more support to run a new foundation.

Hd1: The supports that entrepreneurs with professional work experience and without any professional work experience make the most use of from accelerator programs are different.

Hd2: The supports that entrepreneurs with professional work experience and without any professional work experience benefit the most from accelerator programs are different.

He1: The supports that entrepreneurs with previous entrepreneurship experience in any sector and without any experience make the most use of from accelerator programs are different.

He2: The supports that entrepreneurs with previous entrepreneurship experience in any sector and without any experience benefit the most from accelerator programs are different.

Having an entrepreneur in the immediate family encourage individuals to found a new venture through the help they get from their families. If an individual has an entrepreneur family member, this individual is more likely to start a new venture. Authors such as Albort-Morant and Oghazi [25], Gurel et al. [58] and Singh et al. [59] also support this argument. Having an entrepreneur within the immediate family has a greater effect than having an entrepreneur as an acquaintance. There is a simple reason behind this. Entrepreneurial families also encourage their children to start new businesses because they can guide them through the obstacles they will come across during their entrepreneurship journeys. Since the new entrepreneur can take advantage from the experiences of their families, they can be one step ahead compared to others who doesn’t have any entrepreneurs within their families.

Hf1: The lack of an entrepreneur in the entrepreneur's family grows the need for support from the accelerator program.

Hf2: The lack of an entrepreneur in the entrepreneur's family grows the benefit it takes from the accelerator program.

B. Survey Data

The data of this study were collected by a survey which was conducted to entrepreneurs in the selected accelerator programs between September and December, 2017. The reliability and validity analysis of the survey is performed. The reliability analysis is done using Cronbach’s Alpha method and the value of α for this survey is 0.891 meaning that the survey is very reliable. The content validity analysis is done by asking the feedback of two experts in the field and according to their reviews, the survey was revised. Afterwards, this initially prepared survey was distributed to the entrepreneurs attended in other accelerator programs. In the initial survey, it was analyzed whether the entrepreneurs understood the questions in the way they were supposed to be asked and answered accordingly. In relation to the results of this survey, the questions were reviewed and applied to the same group again. In relation to the results attained, the survey was revised once more and implemented to entrepreneurs who were selected randomly in the target group. This establishes our pilot group of entrepreneurs. Later on, this survey was updated and finalized. As a result, the 4th version of the survey is its final version.

After the final version of the survey is prepared, the coordinators of the chosen accelerator programs were called and a time was scheduled to go to the offices of the accelerator programs in order to collect data from the entrepreneurs. Hard copy of the survey was handed out to entrepreneurs who were present during the visits to collect data. Then, these data were transmitted to the electronic environment. SurveyMonkey is used to bring together data electronically from the entrepreneurs who completed the programs and not present in the time of the visit to the offices of the programs. The link of the survey is first sent to the coordinators of the programs and these coordinators sent the link to the remaining entrepreneurs. Also, the link was posted in in social media groups of our targeted accelerator programs and in other entrepreneurship groups in order to collect more data for the study.

The survey consists of 4 different sections. These are information about entrepreneurs, information about the startup, information about the accelerator and information about the entrepreneur who left the accelerator program. The last section was only filled out by entrepreneurs who graduated from the accelerator program. The survey questions consist of open ended, multiple choice and 5 point likert scale questions. The hypotheses are measured according to the 5 point likert scale questions.

Totally, 162 people participated into our survey but 130 of them filled it out completely. Out of these 130 entrepreneurs, 5 of them were excluded from the study because they had participated in different accelerator programs outside of the targeted ones. These 125 entrepreneurs belong to 106 different startups. The number of men attended the survey is 103 and the number of women is 22. The data received is checked for common method bias using Harman’s single factor analysis in Table I. The variance explained by a single factor is 30.038% which is less than 50%. Thus, it can be determined that the data set don’t suffer from the common method bias issue.

TABLE I. HARMAN’S SINGLE FACTOR ANALYSIS.

Initial Eigenvalues				Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2,103	30,038	30,038	2,103	30,038	30,038
2	1,485	21,210	51,249			
3	1,201	17,151	68,400			
4	0,781	11,161	79,561			
5	0,667	9,533	89,094			
6	0,530	7,571	96,665			
7	0,233	3,335	100,000			
Extraction Method: Principal Component Analysis						

III. Results

The tests of hypotheses and the outcomes of these tests can be found below. Descriptive statistical methods are used to evaluate the study data. In addition to graphical tests, normal distributions of quantitative data are tested using the Shapiro-Wilk test. In order to compare the two groups of quantitative variables that are not normally distributed, Mann-Whitney U test is used. The Kruskal-Wallis test is performed to compare more than two groups of quantitative variables which are not normally distributed. Dunn-Bonferroni test is used to find out the groups that produced significance, if the Kruskal-Wallis test result is significant. In this section, first level “1” hypotheses are tested meaning hypotheses from Ha1 to Hf1. The results of these tests can be found starting from Table II to Table VII. Next, level “2” hypotheses are tested meaning hypotheses from Ha2 to Hf2. The results of these tests can be found starting from Table VIII to Table XIX.

After the univariate analyses, GLMM (generalized linear mixed models) are used in the next section to evaluate the effects of data on support utilization levels of entrepreneurs. Factors affecting each support are evaluated individually in univariate analyses. In models, it is aimed to study the effects of multiple factors on utilization levels together. The results of these tests can be found starting from Table XIX to Table XXVIII.

The supports of accelerators that are going to be analyzed in this study are respectively training, mentorship, office, laboratory, advertising, networking, investment/finance, meeting with investors, going abroad, trademark registration/ patent application/ legal counseling, collaborating with organizations that support the accelerator and technical support because these are the supports that are commonly provided by accelerators. Only the supports that have significant utilization or benefit level differences according to the demographics of entrepreneurs are presented in the study. For example; training and mentorship supports do not have any significant differences in their utilization levels according to the demographics of entrepreneurs. Therefore, Table II represents the next support which is providing an office to the entrepreneur.

A. Univariate Analyses

Demographics that are taken into consideration for this study are gender, age, education, professional work experience and having an entrepreneur in the family or social circle. In the univariate analyses, only the demographics that produce significant results ($p<0.05$) are presented. For example, in Table II, only the effects of age and to have an entrepreneur in the family or social circle is presented because they have significant results on utilization of office services.

In relation to the age (p: 0.045) in Table II, it is significantly different in terms of the usage level of office services. The usage level of entrepreneurs 35 years old and above is lower than the ones under 25 years old (p: 0.049). There is also a significant difference in terms of having an entrepreneur within the family (p:0.031). The office usage level of entrepreneurs without an entrepreneur in their families or social circle is lower than the ones who have entrepreneurs in their families or social circle. The reason of this may be that entrepreneurs with other entrepreneurs in their families know the importance of working in an office more than others. Entrepreneurs who do not have entrepreneurs in their families can also use coffee shops or libraries to work.

In relation to the previous work experiences of entrepreneurs, it is significantly different in terms of the usage level of networking services (p:0.019) in Table III. The utilization level of entrepreneurs with 1-2 years of work experience is higher than the ones with 8 years and more work experience (p:0.045). Someone with 8 years or more experience is expected to have a larger professional network compared to someone with less experience. Therefore, entrepreneurs with more work experience uses the networking support the accelerator provides less than entrepreneurs with fewer work experience.

In Table IV, in respect of the utilization level of going abroad opportunities according to the age (p:0.031), is significantly different. The utilization level of entrepreneurs under 25 years old is higher than the ones between 31 and 35 years old (p: 0.021). This is because as people age, their responsibilities increase as well. For this reason, they do not prefer to go abroad and establish a new life from scratch since going abroad is another risk for entrepreneurs besides founding a new company.

TABLE II. Comparing the Level of utilization of Office Services According to the Demographics of the Entrepreneur

(n:125)		n	Office Services Median (Q1, Q3)	Test value	p
Age	<25	40	5 (4, 5)	8.041	[a]0.045*
	26-30	42	4.5 (3, 5)		
	31-35	27	4 (3, 5)		
	>35	16	4 (2, 4.5)		
There is an Entrepreneur in the Family or Social Circle	Yes	86	5 (4, 5)	-2.157	[b]0.031*
	No	39	4 (3, 5)		

aKruskal Wallis test bMann-Whitney U test *p<0.05
Q1: First quarter, Q3: Third Quarter

TABLE III. Comparing the Level of utilization of Networking Services According to the Demographics of the Entrepreneur

(n:125)		n	Networking Median (Q1, Q3)	Test value	p
Professional Work Experience	None	15	4 (4, 4)	11.735	[a]0.019*
	1-2 years	25	4 (3, 5)		
	3-5 years	28	4 (3, 4)		
	6-7 years	14	4 (4, 5)		
	8 years and above	43	3 (3, 4)		

[a]Kruskal Wallis test *p<0.05 Q1: First quarter, Q3: Third Quarter

TABLE IV. COMPARING THE LEVEL OF UTILIZATION OF GOING ABROAD SERVICES ACCORDING TO THE DEMOGRAPHICS OF THE ENTREPRENEUR

(n:125)		n	Going Abroad Services Median (Q1, Q3)	Test value	p
Age	<25	40	3 (0.5, 4)	8.863	[a]0.031*
	26-30	42	2 (0, 4)		
	31-35	27	1 (0, 2)		
	>35	16	1 (0.5, 3)		
Professional Work Experience	None	15	3 (0, 5)	11.221	[a]0.024*
	1-2 years	25	3 (1, 4)		
	3-5 years	28	1 (0, 3.5)		
	6-7 years	14	0.5 (0, 2)		
	8 years and above	43	1 (0, 3)		

[a]Kruskal Wallis test *p<0.05 Q1: First quarter, Q3: Third Quarter

It is significantly different according to the professional work experiences of entrepreneurs (p:0.024) in Table IV. The usage level of entrepreneurs with 1-2 years of work experience is higher than the ones with 6-7 years of work experience (p:0.043). As entrepreneurs' experience and ability increases, the willingness to take risks decreases. Entrepreneurs with less experience and who are younger prefer to go abroad in order to move their careers forward in a short time.

It is significantly different in terms of the usage level of patent application, legal counseling services and trademark registration according to the age (p:0.022) in Table V. The utilization level of entrepreneurs under 25 years old is higher than the ones between 31 and 35 years old and above 35 years old (correspondingly, p:0.048, p:0.048). Also, it is significantly different in terms of the educational status of entrepreneurs (p:0.004). The utilization level of entrepreneurs with Bachelor's degrees is higher than the ones with Master's degrees (p:0.003). The reason of this may be that entrepreneurs with Master's degrees have already taken classes or seminars about how to register trademarks or apply for patents and thus, they use the support provided by the accelerator program less.

It is significantly different in terms of using the support of collaborating with organizations in relation to the age (p:0.027) in Table VI. The usage level of entrepreneurs under 25 years old is higher than the ones between 31 and 35 years old (p:0.049). Also, statistically significant difference is found in respect of the educational status of entrepreneurs (p:0.024). The usage level of entrepreneurs with Bachelor's degrees is higher than the ones with Master's degrees (p:0.027). Entrepreneurs who are older and more educated are expected to have more network compared to others. Therefore, they can reach more clients and do not need to collaborate with the organizations that support the accelerator compared to younger and less educated entrepreneurs.

TABLE V. COMPARING THE LEVEL OF UTILIZATION OF TRADEMARK REGISTRATION / PATENT APPLICATION / LEGAL COUNSELING SERVICES ACCORDING TO THE DEMOGRAPHICS OF THE ENTREPRENEUR

(n:125)		n	Trademark Registration Services Median (Q1, Q3)	Test value	p
Age	<25	40	3 (1.5, 4)	9.678	a0.022*
	26-30	42	2 (1, 3)		
	31-35	27	2 (0, 3)		
	>35	16	1 (0, 3)		
Educational Status	Before Bachelor's	16	3 (1.5, 3)	10.831	[a]0.004**
	Bachelor's	82	3 (1, 4)		
	Master's and up	27	1 (0, 2)		

[a]Kruskal Wallis test *p<0.05 **p<0.01 Q1: First quarter, Q3: Third Quarter

TABLE VI. COMPARING THE LEVEL OF UTILIZATION OF COLLABORATING WITH ORGANIZATIONS THAT SUPPORT THE ACCELERATOR SERVICES ACCORDING TO THE DEMOGRAPHICS OF THE ENTREPRENEUR

(n:125)		n	Collaborating with Organizations Services Median (Q1, Q3)	Test value	p
Age	<25	40	4 (3, 4.5)	9.147	[a]0.027*
	26-30	42	3 (2, 4)		
	31-35	27	3 (1, 4)		
	>35	16	2.5 (0.5, 4.5)		
Educational Level	Pre-Bachelor's	16	3 (3, 4.5)	7.444	[a]0.024*
	Bachelor's	82	3 (2, 4)		
	and up	27	3 (1, 3)		

[a]Kruskal Wallis test *p<0.05 Q1: First quarter, Q3: Third Quarter

TABLE VII. COMPARING THE LEVEL OF UTILIZATION OF TECHNICAL SUPPORT SERVICES ACCORDING TO THE DEMOGRAPHICS OF THE ENTREPRENEUR

(n:125)		n	Technical Support Services Median (Q1, Q3)	Test value	p
Age	<25	40	2 (1, 4)	13.349	[a]0.004**
	26-30	42	3 (2, 4)		
	31-35	27	1 (1, 3)		
	>35	16	1 (0, 3)		
Educational Status	Pre-Bachelor's	16	2 (1, 3.5)	8.956	[a]0.011*
	Bachelor's	82	3 (1, 4)		
	Master's and up	27	1 (0, 3)		

[a]Kruskal Wallis test *p<0.05 **p<0.01 Q1: First quarter, Q3: Third Quarter

In terms of the usage level of technical support, it is significantly different according to the age (p:0.004) in Table VII. The utilization level of entrepreneurs between 25 and 30 years old is higher than between 31 and 35 years old and above 35 years old (correspondingly, p:0.015, p:0.021). Also, it is significantly different according to the educational status of entrepreneurs (p:0.011). The utilization level of entrepreneurs with Bachelor's degrees is higher than the ones with Master's degrees (p:0.008). This is also very similar to the above results. It can be understood from these analyses that as the age and educational status of entrepreneurs increase, they use the supports of the accelerator programs less.

According to the above analyses and results seen from Table II to Table VII, no statistically significant difference is found in the utilization of accelerator supports between men and women. In relation to the age of entrepreneurs, a significant difference is found in the use of office, going abroad, trademark registration, collaborating with other organizations and technical supports. In terms of the educational status of entrepreneurs, a significant difference is found in the utilization levels of trademark registration, collaborating with other organizations and technical supports. In terms of the previous professional work experience of entrepreneurs, a significant difference is found in the use of networking and going abroad services. It is not significantly different in terms of the utilization of any of the accelerator supports in relation to the previous entrepreneurship experience of entrepreneurs. In relation to having an entrepreneur within the close family or social circle, a statistically difference is found in the usage of office services.

It is significantly different in terms of benefiting from training services according to educational background (p: 0.035) in Table VIII. The benefit level of entrepreneurs with Master's degrees and up is lower than the ones with Bachelor's degrees (p:0.046). The reason of this is because entrepreneurs with higher degrees probably took similar classes in schools and already know the subjects explained in the accelerator program or they can learn these subjects by themselves through researching. Also, it is significantly different according to the social circle of entrepreneur (p:0.038). The benefit level of entrepreneurs without an entrepreneur in their families or social circle is higher than the ones with entrepreneurs in their families or social circle. Entrepreneurs with other entrepreneurs in their families can learn these subjects with the help of their families so they don't benefit as much as the others.

It is significantly different in terms of benefiting from mentoring services according to the age of the entrepreneur (p: 0.011) in Table IX. The benefit level of entrepreneurs between 31 and 35 years old is lower than the ones between 26 and 30 years old (p: 0.013). Also, it is significantly different according to the social circle of entrepreneur (p:0.040). The benefit level of entrepreneurs without an entrepreneur in their families or social circle is higher than the ones with entrepreneurs in their families or social circle. Entrepreneurs without other entrepreneurs in their families can get mentoring support from their families so they don't benefit from this support as much as the others.

It is significantly different according to getting benefit from office services according to the educational background (p: 0.015) in Table X. The benefit level of entrepreneurs with pre-Bachelor's degrees is higher than the ones with Master's degrees and up (p:0.028).

It is significantly different according to getting benefit from laboratory services according to age of the entrepreneur (p:0.049) in Table XI. The benefit level of entrepreneurs between 31 and 35 years old is lower than the ones between 26 and 30 years old (p:0.048).

TABLE VIII. COMPARISON OF THE LEVEL OF RECEIVING BENEFIT FROM THE TRAINING SERVICE TO THE DEVELOPMENT OF THE COMPANY ACCORDING TO THE DEMOGRAPHICS OF THE ENTREPRENEUR

(n:125)		**n**	**Training**	**Test value**	**p**
			Median (Q1, Q3)		
Educational Status	Before Bachelor's	16	4.5 (3, 5)	6.697	[a]0.035*
	Bachelor's	82	4 (3, 5)		
	Master's and up	27	3 (2, 4)		
There is an Entrepreneur in the Family or Social Circle	Yes	86	4 (3, 4)	-2.079	[b]0.038*
	No	39	4 (3, 5)		

[a]Kruskal Wallis test [b]Mann-Whitney U test *p<0.05
Q1: First quarter, Q3: Third Quarter

TABLE IX. COMPARISON OF THE LEVEL OF RECEIVING BENEFIT FROM THE MENTORING SERVICE TO THE DEVELOPMENT OF THE COMPANY ACCORDING TO THE DEMOGRAPHICS OF THE ENTREPRENEUR

(n:125)		**n**	**Mentoring**	**Test value**	**p**
			Median (Q1, Q3)		
Age	<25	40	4 (4, 5)	11.057	[a]0.011*
	26-30	42	4 (4, 5)		
	31-35	27	4 (3, 4)		
	>35	16	4 (3, 5)		
There is an Entrepreneur in the Family or Social Circle	Yes	86	4 (3, 5)	2.053	[b]0.040*
	No	39	4 (4, 5)		

[a]Kruskal Wallis test [b]Mann-Whitney U test *p<0.05
Q1: First quarter, Q3: Third Quarter

TABLE X. COMPARISON OF THE LEVEL OF RECEIVING BENEFIT FROM THE OFFICE SERVICE TO THE DEVELOPMENT OF THE COMPANY ACCORDING TO THE DEMOGRAPHICS OF THE ENTREPRENEUR

(n:125)		**n**	**Office**	**Test value**	**p**
			Median (Q1, Q3)		
Educational Status	Before Bachelor's	16	4 (2.5, 4)	8.366	[a]0.015*
	Bachelor's	82	4 (4, 5)		
	Master's and up	27	3 (2, 4)		

[a]Kruskal Wallis test *p<0.05 Q1: First quarter, Q3: Third Quarter

TABLE XI. COMPARISON OF THE LEVEL OF RECEIVING BENEFIT FROM THE LABORATORY SERVICE TO THE DEVELOPMENT OF THE COMPANY ACCORDING TO THE DEMOGRAPHICS OF THE ENTREPRENEUR

(n:125)		n	Laboratory	Test value	p
			Median (Q1, Q3)		
Age	<25	40	1 (0, 2)	7.837	[a]0.049*
	26-30	42	1 (0, 4)		
	31-35	27	0 (0, 1)		
	>35	16	0 (0, 1)		

[a]Kruskal Wallis test *p<0.05 Q1: First quarter, Q3: Third Quarter

TABLE XII. COMPARISON OF THE LEVEL OF GETTING BENEFIT FROM THE ADVERTISING SERVICE TO THE DEVELOPMENT OF THE COMPANY ACCORDING TO THE DEMOGRAPHICS OF THE ENTREPRENEUR

(n:125)		n	Advertising	Test value	p
			Median (Q1, Q3)		
Age	<25	40	3 (1, 4)	8.168	[a]0.043*
	26-30	42	3 (2, 5)		
	31-35	27	2 (1, 3)		
	>35	16	2 (1, 4)		
Educational Status	Pre-Bachelor's	16	1.5 (0, 2.5)	10.002	[a]0.007**
	Bachelor's	82	3 (1, 4)		
	Master's and up	27	2 (1, 3)		

[a]Kruskal Wallis test *p<0.05 **p<0.01 Q1: First quarter, Q3: Third Quarter

It is significantly different according to receiving benefit from advertising services according to the age of the entrepreneur (p:0.043) in Table XII. The benefit level of entrepreneurs between 26 and 30 years old is higher than the ones between 31 and 35 years old (p:0.038). Also, it is significantly different in terms of getting benefit from advertising services according to the educational status of the entrepreneur (p: 0.007). The benefit level of entrepreneurs with pre-Bachelor's degrees is lower than the ones with Bachelor's degrees (p:0.014).

It is significantly different in terms of benefiting from networking services according to the educational status of the entrepreneur (p: 0.031) in Table XIII. The benefit level of entrepreneurs with Bachelor's degrees is higher than the ones with pre-Bachelor's degrees (p:0.014). Entrepreneurs with Bachelor degrees can achieve a similar network through their college friends or university professors. Therefore, they benefit less from networking support.

It is significantly different in terms of benefiting from investment/finance services according to the age of the entrepreneur (p:0.017) in Table XIV. The benefit level of entrepreneurs between 31 and 35 years old is lower than the ones between 26 and 30 years old (p:0.009). Younger entrepreneurs benefit more from the investment/finance support because they have less capital. Older entrepreneurs may have accumulated more funds until that time frame.

TABLE XIII. COMPARISON OF THE LEVEL OF RECEIVING BENEFIT FROM THE NETWORKING SERVICE TO THE DEVELOPMENT OF THE COMPANY ACCORDING TO THE DEMOGRAPHICS OF THE ENTREPRENEUR

(n:125)		n	Networking	Test value	p
			Median (Q1, Q3)		
Educational Status	Pre-Bachelor's	16	3 (3, 4)	6.956	[a]0.031*
	Bachelor's	82	4 (3, 5)		
	Master's and up	27	3 (2, 4)		

[a]Kruskal Wallis test *p<0.05 Q1: First quarter, Q3: Third Quarter

TABLE XIV. COMPARISON OF THE LEVEL OF RECEIVING BENEFIT FROM THE INVESTMENT/FINANCE SERVICE TO THE DEVELOPMENT OF THE COMPANY ACCORDING TO THE DEMOGRAPHICS OF THE ENTREPRENEUR

(n:125)		n	Investment/ Finance	Test value	p
			Median (Q1, Q3)		
Age	<25	40	3 (1, 4)	10.132	[a]0.017*
	26-30	42	3.5 (2, 5)		
	31-35	27	2 (0, 3)		
	>35	16	3 (1.5, 4)		

[a]Kruskal Wallis test *p<0.05 Q1: First quarter, Q3: Third Quarter

TABLE XV. COMPARISON OF THE LEVEL OF RECEIVING BENEFIT FROM THE MEETING WITH INVESTORS SERVICE TO THE DEVELOPMENT OF THE COMPANY ACCORDING TO THE DEMOGRAPHICS OF THE ENTREPRENEUR

(n:125)		n	Meeting with Investors	Test value	p
			Median (Q1, Q3)		
There is an Entrepreneur in the Family or Social Circle	Yes	86	3 (2, 4)	-2.401	[b]0.016*
	No	39	4 (3, 5)		

[b]Mann-Whitney U test *p<0.05 Q1: First quarter, Q3: Third Quarter

It is significantly different according to getting benefit from meeting with investors services according to the social circle of the entrepreneur (p:0.016) in Table XV. The benefit level of entrepreneurs without an entrepreneur in their families or social circle is higher than the ones with entrepreneurs in their families or social circle. Entrepreneurs with other entrepreneurs in their families can reach investors through their families so they don't benefit from this support as much as the others.

There is statistically significant difference according to getting benefit from going abroad services according to the age (p:0.037) in Table XVI. The benefit level of entrepreneurs between 31 and 35 years old is lower than the ones between 26 and 30 years old (p:0.049). This result is somewhat different than the result in Table III. According to Table III, younger entrepreneurs utilize going abroad services more especially the ones aged below 25 but according to this table, entrepreneurs aged between 26 and 30 benefit from going abroad services the most. It can be concluded from this result that entrepreneurs need to gain some experience before going abroad.

TABLE XVI. COMPARISON OF THE LEVEL OF RECEIVING BENEFIT FROM THE GOING ABROAD SERVICE TO THE DEVELOPMENT OF THE COMPANY ACCORDING TO THE DEMOGRAPHICS OF THE ENTREPRENEUR

(n:125)		n	Going Abroad	Test value	p
			Median (Q1, Q3)		
Age	<25	40	1.5 (0, 4)	8.463	[a]0.037*
	26-30	42	2 (0, 4)		
	31-35	27	0 (0, 2)		
	>35	16	2.5 (0.5, 4)		
There is an Entrepreneur in the Family or Social Circle	Yes	86	1 (0, 3)	-1.984	[b]0.047*
	No	39	3 (1, 4)		

[a]Kruskal Wallis test [b]Mann-Whitney U test *p<0.05
Q1: First quarter, Q3: Third Quarter

According to the social circle of the entrepreneur, it is significantly different according to getting benefit from going abroad services (p:0.047) in Table XVI. The benefit level of entrepreneurs without an entrepreneur in their families or social circle is higher than the ones with entrepreneurs in their families or social circle. Entrepreneurs with families as entrepreneurs have usually a wider network and more opportunities compared to other entrepreneurs. Therefore, they have more to lose, if they go abroad. For this reason, they don't benefit as much from this service.

It is significantly different according to receiving benefit from patent application, legal counseling services and trademark registration (p:0.045) according to the age of the entrepreneur in Table XVII. The benefit level of entrepreneurs between 31 and 35 years old is lower than the ones younger than 25 years old (p:0.049). Older entrepreneurs may have more experience in this subject compared to younger ones and therefore, they benefit less.

It is significantly different according to getting benefit from patent application, legal counseling services and trademark registration (p: 0.007) according to the educational background of the entrepreneur in Table XVII. The benefit level of entrepreneurs with Bachelor's degrees is higher than the ones with Master's degrees and up (p:0.007). More educated entrepreneurs may have previously learned about this subject or taken classes/seminars related to the topic and therefore, need less help compared to less educated entrepreneurs.

It is significantly different according to receiving benefit from collaborating with organizations that support the accelerator according to the educational background of entrepreneurs (p: 0.004) in Table XVIII. The benefit level of entrepreneurs with Master's degrees and up is lower than the ones with Bachelor's degrees (p:0.004).

It is significantly different according to receiving benefit from technical support according to the educational status of entrepreneurs (p: 0.037) in Table XIX. The benefit level of entrepreneurs with Master's degrees and up is lower than the ones with Bachelor's degrees (p:0.049). The reason of this is because entrepreneurs with higher degrees probably took technical classes in schools and already know the subjects or they can learn these subjects by themselves through researching.

TABLE XVII. COMPARISON OF THE LEVEL OF RECEIVING BENEFIT FROM THE TRADEMARK REGISTRATION / PATENT APPLICATION / LEGAL COUNSELING SERVICES TO THE DEVELOPMENT OF THE COMPANY ACCORDING TO THE DEMOGRAPHICS OF THE ENTREPRENEUR

(n:125)		n	Trademark Registration	Test value	p
			Median (Q1, Q3)		
Age	<25	40	3 (1, 4)	8.058	[a]0.045*
	26-30	42	2 (1, 4)		
	31-35	27	1 (0, 3)		
	>35	16	1 (0, 3.5)		
Educational Status	Pre-Bachelor's	16	1.5 (0, 3)	10.051	[a]0.007**
	Bachelor's	82	3 (1, 4)		
	Master's and up	27	1 (0, 2)		

[a]Kruskal Wallis test *p<0.05 **p<0.01 Q1: First quarter, Q3: Third Quarter

TABLE XVIII.COMPARISON OF THE LEVEL OF RECEIVING BENEFIT FROM THE COLLABORATING WITH ORGANIZATIONS THAT SUPPORT THE ACCELERATOR SERVICES TO THE DEVELOPMENT OF THE COMPANY ACCORDING TO THE DEMOGRAPHICS OF THE ENTREPRENEUR

(n:125)		n	Collaborating with Organizations	Test value	p
			Median (Q1, Q3)		
Educational Status	Pre-Bachelor's	16	2.5 (1, 4)	10.927	[a]0.004**
	Bachelor's	82	4 (2, 4)		
	Master's and up	27	2 (0, 3)		

[a]Kruskal Wallis test **p<0.01 Q1: First quarter, Q3: Third Quarter

TABLE XIX. COMPARISON OF THE LEVEL OF RECEIVING BENEFIT FROM THE TECHNICAL SUPPORT SERVICES TO THE DEVELOPMENT OF THE COMPANY ACCORDING TO THE DEMOGRAPHICS OF THE ENTREPRENEUR

(n:125)		n	Technical Support	Test value	p
			Medyan (Q1, Q3)		
Educational Status	Pre-Bachelor's	16	1 (0, 3.5)	6.590	[a]0.037*
	Bachelor's	82	2.5 (1, 4)		
	Master's and up	27	1 (0, 2)		

[a]Kruskal Wallis test *p<0.05 Q1: First quarter, Q3: Third Quarter

According to the above analyses and results seen from Table VIII to Table XIX, in terms of getting benefit from the accelerator supports between men and women, no statistically significant difference exists. In relation to the age of entrepreneurs, it is significantly different according to receiving benefit from mentoring, laboratory, advertising, finance/investment, going abroad and trademark registration services. In relation to the educational status of entrepreneurs, significant difference is found in terms of getting benefit from training, office, advertising, networking, trademark registration, collaborating with other organizations and technical supports. In relation to the previous professional work experience of entrepreneurs, no statistically significant difference is found according to receiving benefit from the accelerator supports. In relation to the previous entrepreneurship experience of entrepreneurs, it is significantly different according to getting benefit from the accelerator supports. In relation to having an entrepreneur within the close family or social circle, statistically difference is found according to getting benefit from training, mentorship, meeting with investors and going abroad supports.

B. Regression Models

1) Research of accelerator support utilization according to entrepreneurship data: GLMM (generalized linear mixed models) are used to evaluate the effects of data on support utilization levels of entrepreneurs. Factors affecting each support are evaluated individually in univariate analyses. In models, it is aimed to study the effects of multiple factors on utilization levels together. While supports are included as dependent variables in the models, factors that are found to have statistically significant ($p < 0.05$) effects in univariate analyses are included as independent variables.

In univariate analyses, none of the demographic factors is found statistically significant on entrepreneurs' utilization level of training, mentorship, laboratory, advertisement, networking, investment/finance, meeting with investors supports. For this reason, no model has been created for these variables. Models are only created for the variables that produced more than one significant result ($p<0.05$) in univariate analyses.

a) Office Support: In the univariate analyses, the effects of age and having an entrepreneur in the family are found to be statistically significant on entrepreneurs' utilization level of office support. As it can be seen in Table XX, it is found that the model in which these two variables are included as independent variables is statistically significant (F: 3.555, p: 0.009). In the model, age and to have an entrepreneur in the family are found to be statistically significant (p: 0.026, p: 0.045, correspondingly). When pairwise comparisons for age variable are examined, it is found that the utilization levels of the entrepreneurs under 25 years old are higher than the utilization levels of the entrepreneurs who are between the ages of 31 and 35 and over 35 years old (p: 0.032, p: 0.014, correspondingly). It is also found that the utilization levels of the entrepreneurs between the ages of 26 and 30 are higher than the utilization levels of the entrepreneurs who are over 35 years old (p: 0.048).

b) In univariate analyses, the effects of age and having professional work experience of entrepreneurs are found to be statistically significant on the level of utilizing going abroad services. As it can be seen in Table XXI, it is found that the model in which these two variables are included as independent variables is statistically significant (F: 3.812, p: 0.001). In the model, age and having professional work experience are found to be statistically significant (p: 0.034, p: 0.036, correspondingly). When pairwise comparisons for age variable are examined, it is found that the utilization levels of the entrepreneurs between the ages of 31 and 35 are lower than the utilization levels of entrepreneurs who are under 25 years old and between the ages of 26 and 30 (p: 0.006, p: 0.011, correspondingly).

According to Table XXI, when the pairwise comparisons for having professional work experience are examined, it is found that the utilization levels of the entrepreneurs with 1-2 years of experience are higher than the utilization levels of entrepreneurs with 3-5 years and 6-7 years of experience (correspondingly, p: 0.045, p: 0.008). The utility levels of entrepreneurs with 8 years or more professional work experience are found to be higher than those of entrepreneurs with 6 to 7 years of experience (p: 0.044).

TABLE XX. THE MODEL CREATED TO DETERMINE THE FACTORS THAT AFFECT THE LEVEL OF OFFICE USE

	Beta	**t**	**p**	**95% Confidence Interval for Beta**
Constant (Intercept)	3.485	9.313	<0.001**	2.744, 4.226
Age (<25)	0.971	2.498	0.014*	0.201, 1.740
Age (26-30)	0.802	1.993	0.048*	0.005, 1.598
Age (31-35)	0.378	0.856	0.394	-0.496, 1.251
Age (>35)	-	-	-	-
Have an entrepreneur in the family or not (Have)	0.470	2.021	0.045*	0.010, 0.930

*p<0.05 **p<0.01

TABLE XXI. THE MODEL CREATED TO DETERMINE THE FACTORS THAT AFFECT THE LEVEL OF GOING ABROAD UTILIZATION

	Beta	**t**	**p**	**95% Confidence Interval for Beta**
Constant (Intercept)	1.625	4.124	<0.001**	0.845, 2.405
Age (<25)	-	-	-	-
Age (26-30)	-0.212	-0.546	0.586	-0.981, 0.556
Age (31-35)	-1.323	-2.798	0.006**	-2.259, -0.386
Age (>35)	-1.068	-1.595	0.113	-2.395, 0.258
Have professional work experience (None)	-0.023	-0.032	0.974	-1.419, 1.374
Have professional work experience (1-2 years)	0.250	0.455	0.650	-0.840, 1.341
Have professional work experience (3-5 years)	-0.665	-1.289	0.200	-1.688, 0.357
Have professional work experience (6-7 years)	-1.090	-2.035	0.044*	-2.150, -0.029
Have professional work experience (8 years and above)	-	-	-	-

*p<0.05 **p<0.01

c) Trademark registration / Patent application / Legal Counseling Support: In the univariate analyses, the effects of age and educational status of entrepreneurs are found to be statistically significant on the level of utilizing trademark registration / patent application / legal counseling services. As it can be seen in Table XXII, the model in which these two variables are included as independent variables is found to be statistically significant (F: 5.230, $p < 0.001$). The effect of the educational status in the model is found to be statistically significant (p: 0.022). However, the effect of age is found to be statistically insignificant (p: 0.320). When pairwise comparisons of educational status are examined, it is found that the utilization levels of entrepreneurs with a bachelor's degree are higher than those of entrepreneurs with a graduate degree (p: 0.006).

d) Collaborating with organizations that support the accelerator: In univariate analyses, the effects of age and educational status of entrepreneurs are found to be statistically significant on the level of entrepreneurs' ability to cooperate with supporting organizations. The model in which these two variables are included as independent variables is found to be statistically significant (F: 5.230, $p < 0.001$). Although the model was meaningful, the effects of age or educational status on the model are not found to be statistically significant (p: 0.128, p: 0.173, correspondingly).

e) Technical Support: In the univariate analyses, the effects of age and educational status of entrepreneurs are found to be statistically significant on the levels of utilizing technical support. As can be seen in Table XXIII, the model in which these two variables are included as independent variables is found to be statistically significant (F: 4.697, p: 0.001). In the model, the effects of age and educational status were statistically significant (p: 0.008, p: 0.024, correspondingly).

According to Table XXIII, when the pairwise comparisons for age variable are examined, the utilization levels of the entrepreneurs between the ages of 26 and 30 are found to be lower than the utilization levels of entrepreneurs under 25, between 31 and 35 and over 35 years old (p: 0.028, p: 0.003, p: 0.033). When pairwise comparisons of entrepreneurs' educational status are examined, it is found that the utilization levels of entrepreneurs with a bachelor's degree are higher than those of entrepreneurs with a graduate degree (p: 0.006).

2) Research of the benefit levels of accelerator supports according to entrepreneurship data: GLMM (generalized linear mixed models) are used to evaluate the effects of data on the level of receiving benefit for company development from the supports of accelerator programs. Factors affecting each support are evaluated individually in univariate analyses. In models, it is aimed to study the effects of multiple factors on benefit levels together. While supports are included as dependent variables in the models, factors that are found to have statistically significant ($p < 0.05$) effects in univariate analyses are included as independent variables.

TABLE XXII. THE MODEL CREATED TO DETERMINE THE FACTORS THAT AFFECT THE LEVEL OF TRADEMARK REGISTRATION / PATENT APPLICATION / LEGAL COUNSELING UTILIZATION

	Beta	**t**	**p**	**95% Confidence Interval for Beta**
Constant (Intercept)	1.177	2.830	0.005**	0.353, 2.000
Age (<25)	0.790	1.439	0.153	-0.297, 1.876
Age (26-30)	0.400	0.781	0.436	-0.613, 1.412
Age (31-35)	0.086	0.164	0.870	-0.948, 1.120
Age (>35)	-	-	-	-
Education (Before Bachelor's)	0.745	1.580	0.117	-0.189, 1.679
Education (Bachelor's)	0.919	2.809	0.006**	0.271, 1.566
Education (Graduate)	-	-	-	-

**p<0.01

TABLE XXIII. THE MODEL CREATED TO DETERMINE THE FACTORS THAT AFFECT THE LEVEL OF TECHNICAL SUPPORT UTILIZATION

	Beta	**t**	**p**	**95% Confidence Interval for Beta**
Constant (Intercept)	1.198	2.619	0.010*	0.292, 2.104
Age (<25)	0.279	0.504	0.615	-0.817, 1.375
Age (26-30)	1.084	2.162	0.033*	0.091, 2.076
Age (31-35)	0.051	0.097	0.923	-0.978, 1.079
Age (>35)	-	-	-	-
Education (Before Bachelor's)	0.747	1.444	0.151	-0.277, 1.771
Education (Bachelor's)	0.869	2.775	0.006**	0.249, 1.489
Education (Graduate)	-	-	-	-

*p<0.05 **p<0.01

In univariate analyses, only educational status is found statistically significant on the level of receiving benefit for company development from the office, networking, collaborating with organizations and technical supports. Only age is found statistically significant on the laboratory and investment/finance supports. Only having an entrepreneur in the family is found statistically significant on meeting with investors supports. For this reason, no model has been created for these variables. Models are only created for the variables that produced more than one significant result ($p < 0.05$) in univariate analyses.

a) Training Support: In univariate analyses, the effects of educational status and to have an entrepreneur in the family are found to be statistically significant on the level of receiving benefit for company development from the training support. As it can be seen in Table XXIV, the model in which these two variables are included as independent variables is found to be statistically significant (F: 4.722, p: 0.005). While the effect of the educational status in the model was significant, it is found that the effect of having an entrepreneur in the family is meaningless (p: 0.006, p: 0.156, correspondingly). When the pairwise comparisons of educational status are examined, it is found that the level of receiving benefit for company development by the training support is higher in entrepreneurs who have Pre-Bachelor's degrees compared to entrepreneurs with Bachelor's degrees and graduate degrees. (p: 0.038, p: 0.001, correspondingly). Similarly, entrepreneurs with Bachelor's degrees are found to receive more benefits for their companies via the training support compared to entrepreneurs with graduate degrees. (p: 0.049).

b) Mentorship Support: In the univariate analyses, the effects of age and to have an entrepreneur in the family are found to be statistically significant on the level of receiving benefit for company development from the mentorship support. As it can be seen in Table XXV, the model in which these two variables are included as independent variables was determined to be statistically significant (F: 5.075, p: 0.001). In the model, the effects of age and having an entrepreneur in the family are found to be statistically significant (p: 0.007, p: 0.005, correspondingly). When the pairwise comparisons of age are examined, it is found that the level of receiving benefit by the mentoring support for the company development is higher in entrepreneurs who are between the ages of 26 and 30 than the level of entrepreneurs who are between the ages of 31 and 35 and over 35 (p: 0.002, p: 0048). Similarly, in entrepreneurs whose age is below 25 years old, it is found that the level of receiving benefit by the mentoring support for the company development is higher than the entrepreneurs between the ages of 31 and 35 (p: 0.026). Also, it is found that the level of receiving benefit by the mentoring support is higher in entrepreneurs without an entrepreneur in their families compared to the ones who have an entrepreneur in their families (p: 0.005).

c) Advertising Support: In the univariate analyses, the effects of age and educational status are found to be statistically significant on the level of receiving benefit for company development from the advertising support. As it can be seen in Table XXVI, the model in which these two variables are included as independent variables is found to be statistically significant (F: 4.585, p: 0.001). In the model, the effects of age and educational status are statistically significant (p: 0.049, p: 0.021, correspondingly). When age-related pairwise comparisons are examined, it is found that the level of receiving benefit by the advertising support for the company development is lower in entrepreneurs who are between the ages of 31 and 35 than the level of entrepreneurs who are under the age of 25 and between the ages of 26 and 30 (p: 0.045, p: 0.010, correspondingly). When pairwise comparisons of educational status are examined, it is found that the level of receiving benefit from advertising support for company development is higher in entrepreneurs who have bachelor's degrees than the level of entrepreneurs with Pre-Bachelor's degrees. (p: 0.007).

TABLE XXIV. THE MODEL CREATED TO DETERMINE THE FACTORS THAT AFFECT THE LEVEL OF RECEIVING BENEFIT FOR COMPANY DEVELOPMENT BY TRAINING SUPPORT

	Beta	**t**	**p**	**95% Confidence Interval for Beta**
Constant (Intercept)	1.499	22.557	<0.001**	1.363, 1.636
Education (Before Bachelor's)	-	-	-	-
Education (Bachelor's)	-0.143	-2.273	0.032*	-0.272, -0.013
Education (Graduate)	-0.308	-3.193	0.002**	-0.500, -0.116
Have an entrepreneur in the family or not (Have)	-0.089	-1.429	0.156	-0.213, 0.035

*p<0.05 **p<0.01

TABLE XXV. THE MODEL CREATED TO DETERMINE THE FACTORS THAT AFFECT THE LEVEL OF RECEIVING BENEFIT FOR COMPANY DEVELOPMENT BY MENTORSHIP SUPPORT

	Beta	**t**	**p**	**95% Confidence Interval for Beta**
Constant (Intercept)	4.449	22.159	<0.001**	4.046, 4.852
Age (<25)	-	-	-	-
Age (26-30)	0.141	0.646	0.521	-0.294, 0.576
Age (31-35)	-0.673	-2.261	0.026*	-1.263, -0.084
Age (>35)	-0.613	-1.498	0.137	-1.423, 0.197
Have an entrepreneur in the family or not (Have)	-0.547	-2.933	0.005**	-0.920, -0.174

*p<0.05 **p<0.01

TABLE XXVI. THE MODEL CREATED TO DETERMINE THE FACTORS THAT AFFECT THE LEVEL OF RECEIVING BENEFIT FOR COMPANY DEVELOPMENT BY ADVERTISING SUPPORT

	Beta	**t**	**p**	**95% Confidence Interval for Beta**
Constant (Intercept)	1.684	4.422	<0.001**	0.926, 2.443
Age (<25)	-	-	-	-
Age (26-30)	0.197	0.509	0.612	-0.570, 0.965
Age (31-35)	-0.742	-2.042	0.045*	-1.467, -0.017
Age (>35)	-0.375	-0.713	0.477	-1.415, 0.666
Education (Before Bachelor's)	-	-	-	-
Education (Bachelor's)	1.179	2.756	0.007**	0.330, 2.027
Education (Graduate)	0.725	1.535	0.129	-0.216, 1.665

*p<0.05 **p<0.01

d) Going Abroad Support: In the univariate analyses, the effects of age and to have an entrepreneur in the family are found to be statistically significant on the level of receiving benefit for company development from the going abroad support. As can be seen in Table XXVII, the model in which these two variables are included as independent variables was found to be statistically significant (F: 4.270, p: 0.003). While the effect of the age variable is statistically significant in the model, it is found that the effect of having an entrepreneur in the family is meaningless (p: 0.015, p: 0.087, correspondingly). When age-related pairwise comparisons are examined, it is found that the level of receiving benefit by the going abroad support for the company development is higher in entrepreneurs who are between 31 and 35 years old compared to ones under 25, between 26 and 30 and over 35 years old (p: 0.012, p: 0.005, p:0.041, correspondingly).

e) Trademark registration / Patent application / Legal Counseling Support: In the univariate analysis, the effects of age and educational status are found to be statistically significant on the level of receiving benefit for company development from the trademark registration / patent application / legal counseling support. As can be seen in Table XXVIII, the model in which these two variables are included as independent variables was found to be statistically significant (F: 4.585, p: 0.001). While the effect of educational status on the model is found to be statistically significant, the effect of age is found to be insignificant (p: 0.017, p: 0.183, correspondingly). When the pairwise comparisons of educational status are examined, it is found that the level of receiving benefit by the trademark registration / patent application / legal counseling support for the company development is higher in entrepreneurs who have Bachelor's degrees compared to the ones who have graduate degrees (p: 0.008).

TABLE XXVII. THE MODEL CREATED TO DETERMINE THE FACTORS THAT AFFECT THE LEVEL OF RECEIVING BENEFIT FOR COMPANY DEVELOPMENT BY GOING ABROAD SUPPORT

	Beta	**t**	**p**	**95% Confidence Interval for Beta**
Constant (Intercept)	2.587	6.100	<0.001**	1.747, 3.426
Age (<25)	-	-	-	-
Age (26-30)	0.127	0.293	0.770	-0.729, 0.983
Age (31-35)	-1.084	-2.578	0.012*	-1.922, -0.247
Age (>35)	0.102	0.175	0.862	-1.057, 1.262
Have an entrepreneur in the family or not (Have)	-0.628	-1.728	0.087	-1.347, 0.092

*p<0.05 **p<0.01

TABLE XXVIII. THE MODEL CREATED TO DETERMINE THE FACTORS THAT AFFECT THE LEVEL OF RECEIVING BENEFIT FOR COMPANY DEVELOPMENT BY TRADEMARK REGISTRATION / PATENT APPLICATION / LEGAL COUNSELING

	Beta	**t**	**p**	**95% Confidence Interval for Beta**
Constant (Intercept)	1.367	3.057	0.003**	0.480, 2.255
Age (<25)	0.591	1.018	0.311	-0.559, 1.741
Age (26-30)	0.158	0.286	0.775	-0.933, 1.249
Age (31-35)	-0.320	-0.588	0.557	-1.399, 0.758
Age (>35)	-	-	-	-
Education (Before Bachelor's)	0.235	0.408	0.684	-0.908, 1.379
Education (Bachelor's)	0.984	2.720	0.008**	0.263, 1.705
Education (Graduate)	-	-	-	-

**p<0.01

IV. DISCUSSION

This research performs a statistical analysis on entrepreneurs' usage of supports provided by the accelerator programs in relation to their demographics. It is studied whether entrepreneurs' gender, age, educational status, work experience and family background affect the need of receiving support from the accelerator program. According to entrepreneurs' backgrounds, it has also been researched which entrepreneurs use and benefit from which services the most. In order to find out this, several statistical analysis and a regression model has been performed in this research and performed to the entrepreneurs in the chosen accelerator programs located in Istanbul, Turkey.

Ratinho [19] made a research with Business Incubators in Europe and investigated how much help tenant companies receive from the incubator to solve their business problems. Incubators don't help the tenant companies to solve all of their problems and can only help solving half of them. Also, he investigated the companies' support seeking habits from the perspective of company age, size and human capital. This study looks at startups' support utilization levels and how much benefit they receive from these supports from the perspective of entrepreneurs' demographics instead of the firms' perspective. It tries to identify which supports/services startups use the most according to entrepreneurs' gender, age, educational status, work experience and family background.

A key finding from this research is that there is no relation with gender in terms of entrepreneurs' usage and getting benefit from the accelerator supports. This finding is similar to Schipper's study on gender [60]. Schipper, et al. [60] made a study with 703 first year college students at Rotterdam School of Management and they evaluated the effects of a brief, evidence-based online interference. According to this study, the gap in accomplishments between men and women became considerably smaller within the intervention cohort. After Year 1, the gender gap closed by 98% meaning that gender doesn't have any impact on academic achievement.

Other key findings from this study is that age and educational background of the entrepreneur affect the most on entrepreneurs' usage and getting benefit from the accelerator supports. As age and the educational status grows, entrepreneurs' need of receiving support and benefiting from these supports decrease. As people get older, they acquire more experiences. Moreover, when they receive more education, they obtain more knowledge. Therefore, older and more educated entrepreneurs receive less support from the accelerator program compared to younger and less educated ones. It is also found out that entrepreneur's family background has a big effect on receiving and benefiting from the supports of the accelerator. Although Hallen, et al. [61] did not find any statistically significant difference on the benefit level of entrepreneurs who have previous entrepreneurship related experience. In this study, it has found that entrepreneurs with entrepreneurs in their close families need less support from the accelerator because they use their families' resources. The reason of this difference may be due to the cultural factors. The study of Hallen, et al. [61] is based on two accelerators located in the US where there is an individualistic culture. On the other hand, this research is based on accelerators located in Istanbul, Turkey where there is a collectivistic culture according to Hofstede Insights [62].

V. Conclusion

This research adds to the nascent literature on accelerators by making an empirical study on entrepreneurs currently participating or previously participated to accelerator programs. The current literature about accelerators mainly researches the processes and business models of the programs in addition to incubators. The literature is lacking a study on accelerator programs and how entrepreneurs attending these programs utilize their services or how much benefit they receive from these programs. If accelerator programs consider the findings in this study, they can enhance their programs. Thus, they can modify the services they provide in relation to the entrepreneurs' requests and can add more to their development. Therefore, as more entrepreneurs and startups become successful, they can contribute more to the economy of their region. Technology initiatives, which are established with low capital and produce high value-added products and services, play a key role in furthering the economies of emerging countries such as Turkey.

There are limitations in this study. First, this study doesn't involve accelerator programs in other countries and is only based on Istanbul, Turkey. Second, it includes entrepreneurs presently participating in the accelerator programs and who graduated recently within the past two years of the programs due to the difficulty of connecting with entrepreneurs who attended the programs more than two years ago. Third, causation is not checked in this study because in order to analyze causation, correlation analysis must be performed. Instead of correlation analysis, regression analysis is preferred in this study due to the fact that the study aims to identify the effect of one or more variables on another by presenting a model. Fourth, response bias should be considered between men and women since they are emotionally different, there may be psychological differences on how they respond to survey questions. Future studies can study entrepreneurs in other countries to explore their needs from the accelerator programs. Moreover, comparative analysis can be done between entrepreneurs attending other accelerator programs in different countries.

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Learning Analytics Tool Adoption by University Students

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***Abstract*—Learning analytics refers to a systematic process involving measuring, collecting, analyzing and reporting data about learners with the aim of fully understanding how best learning environments can be optimized to increase efficiency. The aim of this study is to understand the factors contributing to the learning analytics adoption by university students in North Cyprus. Participants comprised of students from three universities in North Cyprus. 718 valid questionnaires involving items from the adopted UTAUT (Unified Theory of Acceptance and Use of Technology) model was used in the study. The results have shown that there was a weak negative correlation between Performance Expectancy and Technology Use Intention implying that when students are aware of how a technology operates and if it satisfies their requirements, then they will be ready to adopt learning analytics. There was also a negative weak correlation between Effort Expectancy and Technology Use Intention. A positive weak correlation between Social Influence and Technology Use Intention was observed while there was a negative weak correlation between Technology Use Intention and Technology Use Behavior implying that when a students have intentions of using learning analytics, they show a positive behavior towards the technology. The study also shows that there was also moderate positive correlation between Technology Anxiety and Technology User Behavior. This study is considered to be of great benefit and practical implementation to researchers, instructors, students, universities and the ministry of education.**

Keywords*—Higher education; learning analytics; learning tools; North Cyprus; students; technology

I. Introduction

Learning analytics refers to a systematic process involving measuring, collecting, analyzing and reporting data about learners with the aim of fully understanding how learning environments can be optimized to increase efficiency and effectiveness. Various learning analytical tools have been discovered through research and developed in a bid to improve the overall learning experience. Educators play an important role in determining which analytical tool best suits learners considering how the tool supports both pedagogical as well as organizational goals [1]. A digital footprint is left behind each time a student uses a university services as student information system, learning management system, library login, logging in to the virtual learning systems or submitting online assignments. Learning analytics is the process of thoroughly analyzing the digital footprint to get more information about the users of the system which can help enhance the overall learning process [2].

Due to the recent "smart" advancements in the technology sector and considering recent globally emerging covid-19 breakout there is an urgent need to shift from traditional paper and pencil approach to a digitally extracting meaning from students' progress, learning activities etc… and hence moving away from the traditional paper-based usage in an attempt to keep up with the standards of education in North Cyprus due to the increasing number of students for every academic semester. Adopting learning analytics in the educational sector has led to higher retention levels and prediction of drop-outs allowing institutions and instructors to be proactive hence improving the entire learning process in some countries such as Australia, UK, America and Italy [3]. Learning analytics have been used by instructors in improving their overall teaching experience as well as by institutions in fostering good learning practices and improving the entire learning system. In addition, learning analytics can be used to effectively monitor engagements among students and boost participation and to improve attainment levels by offering support to struggling students. For such reasons, understanding the acceptance and adoption of learning analytics play a vital role.

Learning analytics also play a crucial role in improving the overall educational sector and enhancing the learning environment. Below are reasons why learning analytics are important to various educational stakeholders: Learning analytics enable students to monitor their performance based on their set goals and check how others are performing which can endorse motivation. Learning analytics gives more insight to the student on the areas they need to improve in order for them to obtain better grades. The instructors or teachers will be able to monitor their students' progress in real time and get more insight on their performance. Students lagging behind can be easily identified and the instructor will be able to be proactive and assist the students before they fail hence improving retention levels. Training managers will be able to identify educational stakeholders as students or teachers who are lagging behind or are having difficulties in using the system and training managers will be able to focus on problematic groups only. By making use of learning analytics, institutions will be able to retain more students through once proactive measures taken once signals are seen on students underperforming and dropout levels are also minimized. Researchers who are interested in knowing how best learning analytics can be adopted in educational settings will be interested in this study.

II. Literature Review

With the emergence of new technologies and global covid-19 pandemic, the world is now undergoing what is known as data revolution where massive data is being generated from various sources in great speed according to [4] it is projected that the quantity of such data will double its current rate each month. The emergence and adoption of new technology in the educational sector has resulted in a massive influx of data however the emerging issue is that this data has been used inefficiently to improve the entire educational sector [5].

In a recent study conducted by [6], students indicated that although the use of learning analytics has had a significant impact in their personal studies they are not keen on sharing their digital footprints with the university and instructors as they feel it is invasion of privacy. Students feel uncomfortable in the learning environment knowing that all their browsing history will be analyzed by their instructors. However, on the contrary, instructors feel that by gaining access to such valuable data that is the only way they will be able to identify the needs of students and see how best they can help each student at an individual level.

It has also been noted that tools available on the student dashboard to show student progress relative to their own learning goals are motivating although in a number of cases it has also been reported that successful students are the ones who tend to use these tools more compared to struggling students [5]. This shows the need for educating all students on the effective use of such tools so that a vibrant picture and clear results can be derived based on all students despite their intellectual level and ability. It was also noted that an increase in student performance as a result of using learning analytics had a positive impact on other courses as well which the same student is studying. It is also vital to note where [7] reported that objections by students on the use of learning analytics has not been reported in the literature by many researchers.

As technology keeps on advancing each day in different sectors, the educational sector is also not being left behind. Many researchers in the literature have explained the importance of this technology and how it is revolutionizing the educational sector. Some of the advantages for adopting learning analytics in the educational sector can be summarized as:

- As a tool for quality assurance and quality improvement: Learning analytics have been used by instructors in improving their overall teaching experience as well as by institutions in fostering best learning practices and improving the entire learning system. Learning analytics data could be used as a submission for institutions as evidence of support for Teaching Excellence Framework (TEF) applications. At the University of Maryland, it was found out that use of learning analytics resulted in quality teaching and improved student and instructor relationships [2].
- As a tool for boosting retention levels: Using learning analytics helps instructors and the institution to identify students that are at risk and proactive intervention can be done quickly hence retention levels are boosted. At Purdue University, problems related to retention and the identification of students at risk can now be done within the second week and measures are quickly taken which is something that could not be done before [2]. Student data analytics can be used to predict the students who will not make it to the next semester at New York Institute of Technology (NYIT). 75% of the students who do not progress to the next semester would have been predicted at risk by the learning analytics model.
- As a tool used for analyzing differential outcomes among students: Learning analytics can be used to effectively monitor engagements among students and boost participation and to improve attainment levels by offering support to struggling students [6].
- For the development of adaptive learning: This refers to personalized learning that is delivered at an individual basis based on one's capability to retain information and is also based on one's schedule [2].

According to authors in [2], adopting learning analytics in higher education has the power to provide students make well informed decisions on their own by monitoring their overall performance in real time and have control over their progress and what they wish to study based on results projected. A study conducted at Nottingham Trent University in the UK showed that 89% of the students considered signals as positive experiences whilst on the other hand 74% stated that their motivation level was increased by using analytic tools. In addition students reported that by being able to see their own engagement online, it had a positive spur for them to stay engaged.

Researchers in [3] conducted a study at many universities across USA to fully understand the adoption of learning analytics. In the second week of the term, instructors identified problems as far as learning analytics deployment was concerned. Students were in need of help more frequently, however this led to 12% more B grades and C grades and failure rates for grade D and F dropped by 14%.

At Maryland University in the United States, learning analytics through the use of virtual learning environments (VLE) has made it possible for instructors to identify effective teaching strategies that could be deployed on other courses and the analysis which was found made it clear that students who obtain low grades use the system 40% less than those who get C grades or even higher grades [3]. In addition, the researchers conducted a study at California State University found out that students were motivated by the use of the virtual learning system and this increased their passing grades by 25%.

A study conducted at Marist College in New York showed that predictive models were a key to students in giving them early feedback and therefore allowed them to be proactive and this resulted in a 6% increase in student's final grades. Furthermore, study conducted at New York Institute of Technology showed that 74% of dropouts were already predicted by the system and this information is vital to instructors as they can support students who are at risk of dropping out and dropout rates can fall [3].

A study conducted at Nottingham Trent University in the UK showed that there was a strong link with retention levels, a quarter of the students who had low average engagement were able to progress to the second year. In addition there was a strong link with achievement levels as well with 81% of the students graduating with a first class and the ratio was 2:1 degree contrary to the 42% who had low engagement [3]. Learning analytics were used in enhancing student experience and retention rates as well as driving interventions at student module and qualification levels.

In Australia at the University of New England, social media is the main platform that is used in engaging students and promoting learning analytics and this has fostered a sense of community among the students both those studying full time at the university and those studying part time [7]. Furthermore, learning analytics helped instructors to identify which students needed support and helped them in creating probabilities of retention scores. At Wollogong University in Australia, learning analytics were used using a system known as SNAPP and it has the ability of visualizing relationships that exist between participants in real time in the form of a network diagram. This enabled instructors to encourage engagements among students especially those students who were less connected with their peers [7].

It is crucial to know that adapting any new technology has challenges that come with it and this is also the same with the adoption of learning analytics in higher education. The following key points are challenges that have been recorded by research in the literature:

- The adoption of learning analytics in an educational sector implies creating a new culture among all stakeholders in order to adapt to the new processes in place and that calls for change management [8].
- Like every new technology, adopting learning analytics comes with additional costs that must be incurred and this normally affects budgets [9].
- Data plays an important role in the implementation of learning analytics systems as successful implementation relies on both effective data integration and the quality of the data and the main restriction often come in play when data systems are not interoperable [8].
- Lack of dedicated data management systems for the production of datasets within a short space of time [9].

An educator should be able to quickly get an insight of the entire learning process by using learning analytics through the use of effective virtualization techniques to monitor users' movements. Current learning management systems provide little insight as far as data analytics is concerned, mainly the number of users logged in and the time log is reflected. Little or no information is given on the movements of users' online. Given above limitations with most of the current systems, Researchers in [1] proposed a model to help in the adoption of learning analytics known as the Learning Analytics Acceptance Model (LAAM). A learning analytics tool called LOCO-Analyst was used in the study to create the LAAM model and investigate the impact of the aforementioned factors. Learning analytics are provided at varying levels of interest using LOCO-Analyst. The model is centered upon the study by [10] who described perceived usefulness as the extent by which an individual believes that their task performance will be improved as a result of using the system. Furthermore, Ease of use is the extent by which an educator believes that a system will be free of effort.

According to a study done by [11] it was found out that learning analytics varies depending on one's interest whether they are interested in a university, department, specific course or a region. The researcher categorizes the interests into three distinct groups, micro, meso and macro analytics. Researchers in [12] described a model for learning analytics:

- What: This dimension seeks to know the type of information that has been collected, managed and used.
- Who: This seeks to find the actors involved who will ultimately receive results.
- Why: Which objectives will be used in order to analyze the collected data.
- How: Which methods will be used in analyzing available data analytics that are based on four dimensions?

The architecture developed by [2] shows how data from various learning environments is fed into the learning analytics warehouse. Predictive analytics takes place at the center of the architecture resulting in actions being coordinated by the system. Analytics can be visualized in a series of dashboards allowing both students and instructors to engage and compare their progress with others. Using such information allows both instructors and students to plan and set targets. Furthermore, the student consent service available allows students to share their information to certain people therefore maintaining privacy of data captured, Jisc's learning analytics software is available for free to institutions for the first two years and the system is cloud based allowing institutions to share the scalable structure yet maintaining their data and the system can be customized easily.

The Unified Technology of Acceptance and Use of Technology (UTAUT) forms the basis of this study. The study is based on all dimensions in the model. Technology Anxiety is another dimension that is not part of UTAUT that was adopted from a study by [6], [13] however the researchers call this computer anxiety in their study. The modified model used in this study has a total of seven dimensions. These dimensions will be used to find out the determinants of learning analytics adoption by students in North Cyprus.

III. Methodology

A. The Aim and Hypotheses

The study directly aims to evaluate the correlation between the Performance Expectancy and Technology Use in different dimensions as stated in the following stipulated hypothesis as depicted in Fig. 1.

H1: Performance Expectancy (PE) will have a positive effect on learning analytics (LA) Usage Intention on the adoption of learning analytic tools in higher education.

H2: Effort Expectancy (EE) will have a positive effect on LA Usage Intention on the adoption of learning analytic tools in higher education.

H3: Social Influence (SI) will have a positive effect on LA Usage Intention on the adoption of learning analytic tools in higher education.

H4: LA usage intention will have a positive effect on LA Usage Behavior on the adoption of learning analytic tools in higher education.

H5: Facilitating Conditions (FC) will have a positive effect on LA Usage Behavior of learning analytics tool adoption.

H6: LA Anxiety will have a positive effect on LA Usage Behavior when it comes to learning analytics tool adoption.

B. *The Research Model*

The research model that will be used in this study comprises of the Unified Technology of Acceptance and Use of Technology (UTAUT) model by [14] which was modified and another dimension Technology anxiety was added. The model used in this study was adopted from a study by [6] and [13]. The model comprises of 7 dimensions namely performance expectancy, effort expectancy, social influence, technology use intention, technology use behavior, facilitating conditions and technology anxiety. The aim of the study is to explore these dimensions and find out to what extent does each dimension affects determinants of learning analytics tools used by students which the proposed model was depicted in Fig. 1.

C. *The Participants*

Participants who took part in this study were students were currently studying at three universities in North Cyprus. In the time of the study, the total population of 102944 students were studying in North Cyprus. Given that the margin of error is 5%, a normal distribution expected and 95% confidence interval it then means that the recommended sample size will be 383. This makes the sample size of 718 participants satisfactory for further analysis.

The participations were voluntary, meaning anyone was free to take part in the study. Furthermore the participant information was anonymously recorded, no personal information was collected that could be used to trace back the participant. Due to several departments at the universities with students specializing in various fields, in this study for the purpose of data analysis participants' department information was divided into two distinct categories namely STEM (Sciences, Technology, Engineering and Mathematics) specifically for students with a technical background and others for non-technical students.

The total number of questionnaires that were distributed were 800. A total of 718 questionnaires which were considered as valid and were further entered into SPSS for analysis. Descriptive statistics and bivariate correlations were used in analyzing the data.

D. *The Demographics of the Participants*

The majority of the students were in the age group 17-26 which totaled 334 (46.5%), followed by age group 27-36 years which were 231 students which constituted 32.2% of the total participants and the last age group 37 years and above had 153 students (21.3%) and this group was mainly dominated by PhD students and a few masters students.

In addition, among the three distinct levels of study, a lot of the participants were undergraduate students who comprised of 391 students (54.5%) of the total participants. Masters students who took part in the study were 244 (34%) and PhD students were 83 (11.5%). The numbers narrow down as the levels go higher in any educational setting. The STEM department which comprised of students in technical fields and science subjects totaled 424 (59.1%) whereas those from other departments were 294 (40.9%).

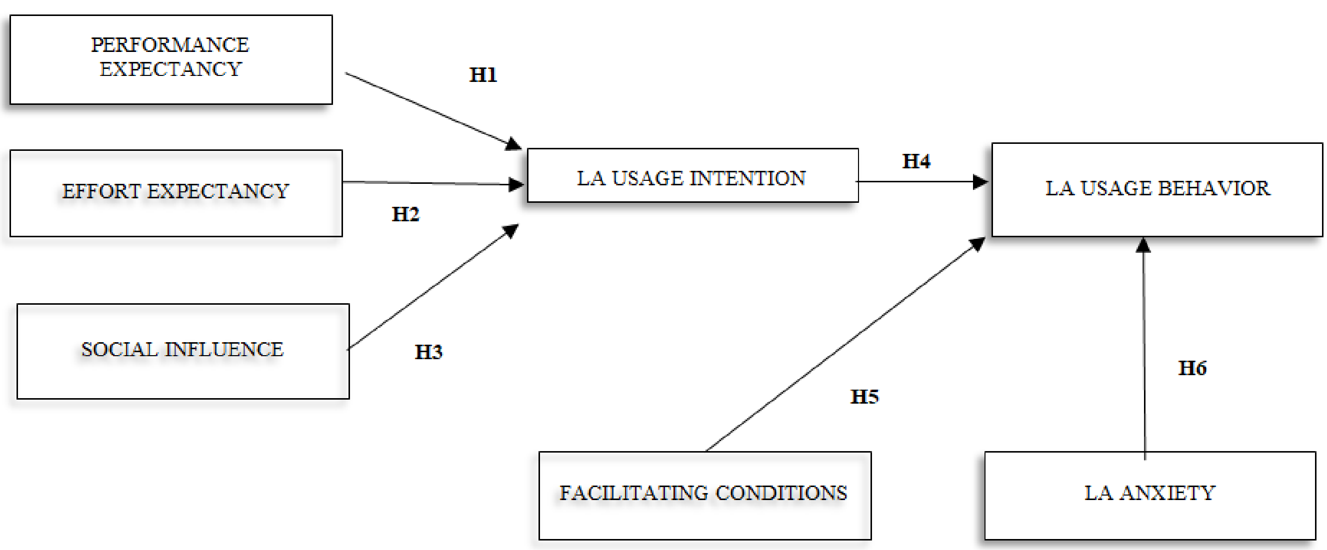

Fig. 1. The Research Model of the Study.

E. The Data Collection

A paper based questionnaire was used to obtain information from participants. The questionnaire had a total of 28 questions with the first part asking general demographic data. The other seven dimensions, Performance Expectancy, Effort Expectancy, Social Influence, Learning Analytics Usage Intention, Learning Analytics Usage Behavior, Facilitating Conditions and Learning Analytics Anxiety were based on a 5 Likert scale. Apart from the 4 questions that were based on the demographic data of the participant. The learning analytics was described in detailed through examples. The Table I represents the items corresponds to the aforementioned dimensions.

F. Reliability

The Cronbach's alpha internal consistency coefficient was used to check reliability in SPSS. Acceptable reliability should range from 0.6 coefficient going upwards, anything less than that is considered unacceptable and amendments must be done until a satisfactory result is obtained [15]. As shown in the Table II, all the dimensions had a reliability of more than 0.6 coefficient which meant all dimensions had satisfactory internal consistency.

TABLE I. THE ADOPTED QUESTIONNAIRE

Section II: PERFORMANCE EXPECTANCY	
1.	I think Learning analytics will increase my productivity.
2.	I think Learning analytics enables me to accomplish tasks quicker.
3.	I think Learning analytics allows me to access more information about my courses.
Section III: EFFORT EXPECTANCY	
4.	Using learning analytics will be easy and intuitive.
5.	I find learning analytics tools easy to use
6.	I believe it would be so easy for me to become skillful at using learning analytics tools.
Section IV: SOCIAL INFLUENCE	
7.	People who influence my behaviour think I should use learning analytics tools.
8.	My supervisors have been helpful in introducing learning analytics tools to me.
9.	People who are important to me think I should use learning analytics tools.
10.	I will use learning analytics even if no one I know is using it.
Section V: LEARNING ANALYTICS USAGE INTENTION	
11.	I predict my university will use learning analytics tools in the next months.
12.	My university intends to use a learning analytics tools in the near future.
13.	My university plan to use learning analytics tools in the distant future.
14.	I intend to use learning analytics tools in the future
15.	I predict I will use learning analytics tools in the next months.
16.	My university has recently started using learning analytics tool.
17.	My university has already been using learning analytics tool for a while.
Section VI: LEARNING ANALYTICS USAGE BEHAVIOR	
18.	I often access learning analytics tools using the internet.
19.	The university has been of help in enabling me to use learning analytics.
20.	I am willing to use learning analytics in my studies.
21.	Using learning analytics tools will lead to a better overall learning experience
Section VI: FACILITATING CONDITIONS	
22.	I have the resources necessary to use learning analytics.
23.	I have the knowledge necessary to use learning analytics.
24.	Learning analytics tools are compatible with other learning tools I use.
Section VIII: LEARNING ANALYTICS ANXIETY	
25.	I feel apprehensive about using learning analytics tools.
26.	It scares me to think that I could lose a lot of information using learning analytics tool by hitting the wrong key.
27.	I am hesitant to use learning analytics for fear of making mistakes which I cannot correct.
28.	Learning analytics tools are somehow intimidating to me.

TABLE II. QUESTIONNAIRE CONSTRUCTS AND RELIABILITY TESTS

Constructs:	Number of Items	Cronbach's Alpha
Performance Expectancy(PE)	3	.688
Effort Expectancy(EE)	3	.675
Social Influence(SI)	4	.684
LA Usage Intention(LAUI)	7	.774
LA Usage Behaviour(LAUB)	4	.706
Facilitating Conditions(FC)	3	.794
LA Anxiety(LAA)	4	.756
TOTAL	28	.851

IV. RESULTS AND DISCUSSION

A. *The Relationship between Performance Expectancy (PE) and Learning Analytics usage Intention*

A Pearson Correlation was computed in order to understand the nature of the relationship existing between the independent and dependent variables. There was a weak negative correlation between Performance Expectancy and Learning Analytics Usage Intention as shown by the following values; r=-.075, n=718 and p=.044. Since p <= 0.05, it was concluded that there is a relationship between the two aforementioned variables. This means that if students are aware of how learning analytics operates and if it satisfies their requirements, they will be ready to adopt learning analytics into their education.

B. *The Relationship between Effort Expectancy (EE) and Learning Analytics usage Intention*

A Pearson Correlation was computed in order to understand the nature of the relationship existing between the independent and dependent variables. There was a weak negative correlation between Effort Expectancy and Technology Use Intention as shown by the following values; r = -.197, n=718 and p=.000. Since p <= 0.05, There exists a relationship between the two aforementioned variables. This implies that when students perceive that little or no effort is needed for one to master learning analytics, they are keen on adopting the technology.

C. *The Relationship between Social Influence (SI) and Learning Analytics usage Intention*

A Pearson Correlation was computed in order to understand the nature of the relationship existing between the independent and dependent variables. There was a weak positive correlation between Social Influence and Learning Analytics Usage Intention as shown by the following values; r= .045, n=718 and p=.224. Since p > 0.05. It was concluded that there is no relationship between the two aforementioned variables. This means that friends and family have no influence on one owns decision when it comes to using learning analytics, it is independent decision. This means that even if peers are using learning analytics tools in their studies one may still decide not to use, close associates have no influence. Close associates such as friends and family have a positive influence in the technology that one uses. If fellow friends and family members are already using learning analytics for their studies they are most likely to influence non-users who will eventually adopt to the new technology. Further investigations may be required to understand variations in results.

D. *The Relationship between Learning Analytics usage Intention and Learning Analytics usage behavior*

A Pearson Correlation was computed in order to understand the nature of the relationship existing between the independent and dependent variables. There was a weak negative correlation between Learning Analytics Usage Intention and Learning Analytics Usage Behavior as shown by the following values; r =-.179, n=718 and p=.000. Since p <= 0.05, we accept the hypothesis and conclude that there is a relationship between the two aforementioned variables. This mean that one's behavior towards using learning analytics is strongly determined by his or her intention to use the technology now or in future. When students intend to use learning analytics they show a positive behavior towards the technology whereas when one does not intend to use the technology they tend to show negative attitude.

What students exhibit is a clear sign of whether they intend to use learning analytics now or in future. A negative behavior is often associated with students who are not keen on adopting the technology.

E. *The Relationship between Facilitating Conditions (FC) and Learning Analytics usage behavior*

A Pearson Correlation was computed in order to understand the nature of the relationship existing between the independent and dependent variables. There was a strong positive correlation between Facilitating Conditions and Technology Use Behavior as shown by the following values; r = .734, n=718 and p=.000. Since p <= 0.05. It was concluded that there is a relationship between the two aforementioned variables. This means that the way a student behaves towards using learning analytics is strongly influenced by other factors that contribute towards accepting the technology such as if they have the resources needed, do they have the knowledge required and will the technology be compatible with other learning tools they are currently using. All these are facilitating conditions that affect user behavior. This means that several factors should be considered prior to adoption and if all factors considered by the student are considered ideal then their behavior towards the usage of learning analytics change. The facilitating conditions can be changed to suit students need and that will result on a positive effect on behavior, for example if one of the factors that students consider as important is compatibility, it is important for educational institutions to make sure that learning analytic tools introduces can easily be integrated into current learning tools. The use of learning analytics can improve student retention which has an impact on the intention to use as suggested by [16]. Additionally, researcher in [16] reported that learning analytics usage provides aid to remedial students suggesting additional learning resources and customize learning progress and enhancing student achievement.

F. The Relationship between Learning Analytics Anxiety and Learning Analytics usage behavior

A Pearson Correlation was computed in order to understand the nature of the relationship existing between the independent and dependent variables. There was a moderate positive correlation between Technology Anxiety and Technology Use Behavior as shown by the following values; $r = .503$, $n=718$ and $p=.000$. Since $p <= 0.05$, It was concluded that there is a relationship between the two aforementioned variables. If students are afraid of using technology they tend to portray a negative behavior towards the technology and if they are curious to try the technology then they are likely to portray a positive behavior.

Technical anxiety, learning analytics anxiety in particular is defined as a feeling of uneasiness when it comes to the use of new technology hence learning analytics. The technology anxiety affects user behavior when it comes to adoption of new technology. The researchers encouraged educational institutions to first make students comfortable with using technology prior to adoption that way successful adoption will be achieved.

Fig. 2 illustrates the research model of the study, the r values between each independent and dependent variables. In addition, Table III represents the results of the study with correlation coefficients as described earlier. It is clearly seen that five of the hypothesis were supported and the dashed lines showed that there was no significant correlation between the two variables.

To sum up, there was a weak negative correlation between Performance Expectancy and Learning analytics usage Intention implying an inverse relationship between the two variables as one variable increased, the other variable decreased. This hypothesis was supported meaning there is a relationship between PE and LAUI. When students are aware of how a technology operates and if it satisfies their requirements they will be ready to adopt learning analytics into their education. There was also a negative weak correlation between Effort Expectancy and Learning Analytics Usage Intention implying an inverse relationship between the two variables as one variable increased, the other variable decreased. This hypothesis was also supported meaning there is a relationship between EE and LAUI. When students perceive that little or no effort is needed for one to master learning analytics they are keen on adopting the technology.

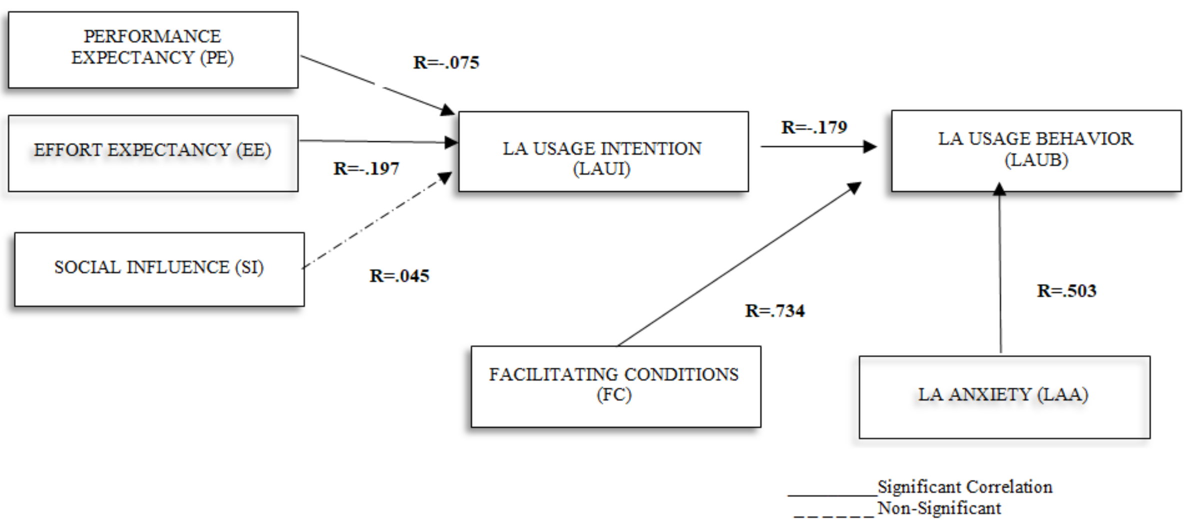

Fig. 2. Summary of Findings and Correlations.

TABLE III. SUMMARY OF FINDINGS

Hypothesis	IV	DV	Supported	Correlation coefficient (+/-Positive/Negative)	R value
H1	PE	LAUI	Yes	Weak -	-.075
H2	EE	LAUI	Yes	Weak -	-.197
H3	SI	LAUI	No	Moderate +	.045
H4	LAUI	LAUB	Yes	Weak -	-.179
H5	FC	LAUB	Yes	Strong +	.734
H6	LAA	LAUB	Yes	Moderate +	.503

There was also a positive weak correlation between Social Influence and Learning analytics usage Intention implying that as one variable increase, the other variable decrease. This hypothesis was rejected meaning there is no relationship between SI and LAUI when it comes to learning analytics. This means that friends and family have no say as to influence ones decision when it comes to using learning analytics, it is ones independent decision. This mean that even if peers are using learning analytics tools in their studies one may still decide not to use, close associates have no influence.

There was a negative weak correlation between Learning Analytics Usage Intention (LAUI) and Learning Analytics Usage Behavior (LAUB) implying an inverse relationship between the two variables as one variable increased, the other variable decreased. This hypothesis was also supported meaning there is a relationship between LAUI and LAUB. This mean that one's behavior towards using learning analytics is strongly determined by his or her intention to use the technology now or in future. When students intend to use learning analytics they show a positive behavior towards the technology whereas when one does not intend to use the technology they tend to show negative attitude.

There was a strong positive correlation between Facilitating Conditions and Learning Analytics Usage Behavior meaning as one variable increase, the other variable also increase. This hypothesis was supported meaning there is a strong relationship between FC and LAUB. This means that the way a student behaves towards using learning analytics is strongly influenced by other factors that contribute towards accepting the technology such as if they have the resources needed, do they have the knowledge required and will the technology be compatible with other learning tools they are currently using. All these are facilitating conditions that affect user behavior.

There was a moderate positive correlation between Learning Analytics Anxiety (LAA) and Learning Analytics Usage Behavior. This means that as one variable increase, the other variable also increase. This hypothesis was supported meaning there is a relationship between LAA and LAUB. If students are afraid of using technology they tend to portray a negative behavior towards the technology and if they are curious to try the technology then they are likely to portray a positive behavior.

In a systematics review study carried out with 43 papers in the related literature by researchers in [17], 12 studies were related to benefits of using Learning analytics and how users perceptions about using LA tools among other aspects as; student retention, assessment, customized learning experiences, usefulness of LA tools, satisfaction, interactions, development, self-reflection, engagement, design of learning and scenarios. Researchers in [18] remarked that students anticipate learning analytics tool that they intend to use or already using should backup and organize their learning progress, should give insights about the progress, should communicate and adjust their needs instantly, and display the outcomes of all learning activities. Researchers in [19] addressed that The Technology Acceptance Model (TAM) proposed by [10] and the Universal Technology Adoption and Use Theory (UTAUT) proposed by [14] which investigates the human factors related to adoption of specific technologies, including perceptions, beliefs, attitudes are particularly relevant for learning analytics adoption theories. Some studies yield to contradictory findings that although learning analytics tools adoption promise improvement in learning, the actual contribution to the educational practice has minor impact but it has been improving towards gaining deeper insights regarding students' learning processes [20].

V. Conclusion

In conclusion, students apparently are keen on adopting learning analytics. This is so because five of six hypothesis used were significantly supported by the results. Students indicated that they have study applications from Play Store they use with a customized dashboard and reminders on their phones also inform them that it is now time to study and to switch subjects. This is evidence that the mobile devices already in use can be used even more effectively for learning analytics. It is also crucial for institutions to embark on workshops to educate both students and instructors on the benefits of adopting to this technology. Students' learning analytics use should be endorsed by the institutions and training programs on using learning analytics tool should be provided to students, instructors and academic advisors.

VI. Suggestions

- The study only focused at a small population of students at three universities only. We strongly recommend a larger population group to be considered in future to really give a better view of the technology and its acceptance levels.
- The study only focused at understanding the determinants of adopting learning analytical tools in education with a strong focus on student perspective. Future research is strongly recommended that will focus on instructors to fully understand both perspectives.
- Institutions should come up with policies that encourage adoption of such technologies and implement workshops so that it will yield in successful adoption as all key stakeholders will be aware of what is required of them.
- Computer basics are the foundation of understanding how learning analytical tools work. It is therefore crucial for institutions to make such studies compulsory among all disciplines whether technical or non-technical.

Instructors as decision makers should be equipped with emergent skills in collecting, interpreting and analyzing student progress and learning and proposing remedial solutions [21]. New data mining competences will be inevitable in future not only for instructors but also for students. Along the same lines, more user-friendly tools will have to be introduced and tested by e-learning faculty. The integration of learning analytics with social media tools will enable instructors to make more effective, efficient timely decisions on the learning progress of students [22].

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Effective Voice Frame Shrinking Method to Enhance VoIP Bandwidth Exploitation

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***Abstract*—The traditional telecommunication system (e.g. landline telephone system) are increasingly being replaced by Voice over Internet Protocol (VoIP) systems because of the very low or free rate. However, one of the main handicaps of VoIP adoption is the inefficient bandwidth exploitation issue. A key approach to handle this issue is packet multiplexing. This article proposes a new VoIP packet payload compression method that enhances bandwidth exploitation over Internet Telephony Transport Protocol (ITTP) protocol. The proposed method is called payload shrinking over ITTP (ITTP-PS). As the name implies, the proposed ITTP-PS method shrinks the VoIP packet payload based on a certain mechanism. The ITTP-PS method has two entities, namely, sender ITTP-PS (S-ITTP-PS) and receiver ITTP-PS (R-ITTP-PS). The main function of the S-ITTP-PS entity is to shrink the VoIP packet payload, while the main function of the R-ITTP-PS entity is restoring the VoIP packet payload to its normal size. To perform the R-ITTP-PS entity function, the ITTP-PS method will reemploy the flag bits in the IP protocol header. The ITTP-PS method has been implemented and compared with traditional ITTP protocol without shrinking the VoIP packet payload. The comparison based on the VoIP packet payload shrinking ratio and isochronous calls capacity improvement ratio. The result showed that the VoIP packet payload shrinking ratio has enhanced by up to around 20%, while the isochronous calls capacity improvement ratio has enhanced by up to around 9.5%. Therefore, enhancing the VoIP bandwidth exploitation over ITTP protocol.**

***Keywords*—VoIP; VoIP protocols; ITTP protocol; payload compression; bandwidth exploitation**

I. Introduction

The wide spreading of the Internet has produced a massive number of technologies such as Voice over Internet Protocol (VoIP) [1][2]. As the name implies, VoIP is an IP based technology to make voice calls. VoIP has become ubiquitous and progressively replaces the old public switched telephone network. The ubiquitous of VoIP resulting from i) the big number of VoIP applications that provide a low rate or free VoIP calls, ii) VoIP applications can be used by any handheld device such as mobile phone, iPad, and laptop, and iii) the useful services that can be accompanied by VoIP calls including interactive voice recognition and transfer the voicemail to email [3][4]. Nevertheless, bandwidth exploitation and quality of service are the two main issues that slow the VoIP propagation [4][5]. This article focuses on VoIP application bandwidth exploitation.

The main cause of the inefficient exploitation of bandwidth is the large header of the VoIP packet in comparison to VoIP packet payload [6][7]. On one hand, VoIP uses a codec to generate a VoIP packet's payload. Codec is hardware or software that captures analog voice signals, converts voice signals into digital signals, compresses the resulting digital data to save bandwidth, and produces a voice frame (a packet's payload). Typically, given that VoIP technology is delay-sensitive (the acceptable delay is 150 ms), the codec produces a voice frame within a short period. Accordingly, the resultant voice frame size typically ranges from 10 bytes to 30 bytes depending on the used codec. Table I shows some of the renowned voice codecs [8][9]. On the other hand, The VoIP packet header constitutes of IP protocol and media transfer protocol such as the 6-bytes internet telephony transfer protocol (ITTP) and the 12-bytes RTP protocol. In the case of ITTP, adding 26 bytes ITTP/IP header to the small payloads (10 to 30 bytes) lead to substantial bandwidth wasting between around 47% and 73% [10][11]. Fig. 1 shows the VoIP packet format when using ITTP protocol. Several approaches have been proposed by the researchers to improve VoIP bandwidth exploitation such as VoIP packet multiplexing, VoIP packet header compression, and VoIP packet payload compression [5][12][13]. This article proposes a new VoIP packet payload compression method to improve VoIP bandwidth exploitation over ITTP/IP protocols. Different from the existing methods, the proposed method focuses only on compress the voice frame without packet multiplexing. Moreover, the proposed method will not add any additional information header to the ITTP/IP packet header, because the proposed method reemploys and utilizes the existing fields of the IP protocol header.

The rest of this paper is organized as follows. Section 2 some of the researcher's effort to enhance bandwidth exploitation over RTP and ITTP protocols. Section 3 discusses the components, mechanism, and process of the proposed shrinking method. Section 4 implements the proposed method and verifies its performance. Finally, Section 5 concludes the paper.

TABLE I. Renowned VoIP Codecs

Codec Name	**G.723.1**	**G.726**	**LPC**	**G.729**	**G.728**
Frame Size (B)	20	30	14	10	10
Bit Rate (kbps)	5.3	24	5.6	8	16

Fig. 1. ITTP VoIP Packet Format.

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II. Related Works

The researchers have exerted a considerable effort to enhance VoIP application bandwidth exploitation. This section spotlight some of these efforts over both RTP and ITTP protocols.

The first approach to enhance VoIP application bandwidth exploitation is packet multiplexing. Multiplexing approach works by grouping the VoIP packets that are sharing the same destination in one header, instead of a separate header to each packet, which highly improves bandwidth utilization. One of the best multiplexing methods over RTP protocol was proposed and patented by Vulkan, Csaba, et al. in 2014. The proposed method performs the packet multiplexing process at the sender side gateway. In which, several packets that are sharing the same destination will be grouped in one large packet with a single UDP/IP header. The packets are accumulated in the large packets until it reached a specific size or for a predefined period of time. At the receiver side gateway, the large packet is segregated, and the original packets are constructed and transmitted to their destinations [14]. Over ITTP, one of the first multiplexing methods is ITTP-Mux (ITTP-Multiplexing) which was proposed in 2015. ITTP-Mux consists of two entities, namely, stream multiplexer (S-Mux) at the sender side gateway and stream de-multiplexer (S-DMux) at the receiver side gateway. At first, the S-Mux separates the packet payload (ITTP and voice frame) from the IP header. Then, a 1-byte header is attached to the packet payload which constitutes a mini-packet. After that, several mini-packets are grouped in one IP header. Finally, the resulted multiplexed packet is transmitted to its destination. The S-DMux segregates the received multiplexed packet by inspecting the 1-byte header. Then, the S-DMux removes the 1-byte header of each mini-packet and attaches the IP header to construct the original packet. Finally, the original packets are transmitted to their destination. The performance evaluation of the ITTP-Mux showed that the bandwidth exploitation has enhanced by up to 29.1% in comparison to the traditional method [10].

The second approach to enhance VoIP application bandwidth exploitation is header compression. Sandlund and Pelletier have proposed then standardized a method that compacts the RTP/UDP/IP header from 40bytes to 2 or 4 bytes. The proposed method achieves this high compression based on two main features of the RTP/UDP/IP header. First, the majority of this header data is not changing throughout the call time. Therefore, these fields are sent when establishing the call and removed from the residual of the packets. Second, some of the remaining data in the header are incremented by steady value. Therefore, these values can be removed from the header and calculated based on a specific equation at the receiver side [15]. Sze et al. proposed another header compression method to enhance VoIP application bandwidth exploitation. However, the proposed method has been implemented with the packet multiplexing approach. It consists of the multiplexer (MUX) module at the sender side gateway and the demultiplexer (DEMUX) module at the receiver side gateway. The MUX module separate the RTP/UDP/IP header from the incoming VoIP packets, compact the RTP header, reattach the compacted RTP header to the voice frame to produce a mini-packet, combine multiple mini-packets in one large packet, and attaches the UDP/IP header to this large packet. The DEMUX module performs a reverse process of the MUX module to reconstruct the original VoIP packets and then, transmit them to their destinations. The size of the large packet is controlled based on the delay, where, if the delay reaches specific value then the multiplexing process is stopped. The performance evaluation of the proposed method showed that bandwidth exploitation has highly enhanced in comparison to the traditional method [16].

The third approach to enhance VoIP application bandwidth exploitation is packet payload compression. The payload compression can be achieved by the VoIP codec, which highly compresses the voice data during generating the voice frame. In addition, payload compression can be achieved by voice activity detection (VAD) technology, which based on the fact that one of the call ends is speaking and the other one is listening. Therefore, VAD suppresses the silence instead of sending it, which highly saves the bandwidth [3][17]. Another method to compress the packet payload, called Delta-Multiplexing, was proposed by Abualhaj et al. in 2010. However, as the name implies, the Delta-Multiplexing method has been implemented with the packet multiplexing approach. Similar to the method proposed by Sze et al. 2002, the Delta-Multiplexing method consists of two modules, Mux and DMux, that perform almost the same process of MUX and DEMUX modules, respectively. However, instead of compressing the packet header, the Mux compresses the packet payload. This is done by calculating the difference between the consecutive voice frame based on a specific mechanism, thus, reduces the voice frame size. Then, transmit this difference instead of the full voice frame, thus, enhances the bandwidth exploitation. In addition, the Delta-Multiplexing method has been added a 12-bits mini-header to the multiplexed mini-packets to be able to restore the original voice frame size and the original VoIP packet. The performance evaluation of the Delta-Multiplexing showed that bandwidth exploitation has enhanced by up to 72% in comparison to the traditional method [3]. A very similar method to Delta-Multiplexing was proposed in 2019 but over ITTP protocol. In which, several VoIP packets are multiplexed in one IP header, the same mechanism of packets payload compression is used, and a 1-byte mini header has been added to the mini-packets to be able to restore the original voice frame size and the original VoIP packet. The performance evaluation of the proposed method showed that bandwidth exploitation has highly enhanced in comparison to the traditional method of ITTP protocol [18]. This article proposes a new payload compression method to enhance bandwidth exploitation over ITTP protocol. Unlike the discussed payload compression methods, the proposed method focuses only on compact the voice frame without multiplexing. In addition, no extra header is needed to restore the original size of the voice frame, because the proposed method reemploys and utilizes the existing fields of the IP protocol header. The proposed method is called payload shrinking over ITTP (ITTP-PS). The following section discusses the proposed ITTP-PS method in detail.

III. Payload Shrinking Over ITTP (ITTP-PS) Method

The key objective of the ITTP-PS method is to shrink the voice frame and therefore lessens its size. This leads to improves the VoIP applications bandwidth exploitation. The ITTP-PS method will be deployed at the VoIP gateway that connected to the wide area network (WAN) connection, though it can be deployed at the client end. Several advantages can be gained by deploying the ITTP-PS method at the VoIP gateway, including i) the proposed ITTP-PS method is workable with the other bandwidth exploitation approaches, such as VoIP packet multiplexing and VoIP header compression, which are typically deployed at the VoIP gateway, ii) the flexibly of using any client application from any device because it does not need to support ITTP-PS method, iii) the ITTP-PS method need to be deployed once at the VoIP gateway instead of each client, and iv) there is, typically, a plenty of bandwidth in local area network in comparison to WAN connections, where the bandwidth is limited and expensive [14][15][19][20]. Fig. 2 displays the location of the ITTP-PS method in a typical VoIP network topology. As shown in Fig. 2, the ITTP-PS method has two entities. The first entity called sender ITTP-PS (S-ITTP-PS). The main function of the S-ITTP-PS entity is to shrink the voice frame to generate a smaller one named S-F. The second entity called receiver ITTP-PS (R-ITTP-PS). The main function of the R-ITTP-PS entity is restoring the S-F to its normal size and generate an original-size voice frame named O-F. The following two subsections discuss the S-ITTP-PS and R-ITTP-PS entities, respectively.

A. S-ITTP-PS Entity Function

The S-ITTP-PS entity performs four main functions to shrink the voice frame: i) detach the VoIP packet header (ITTP/IP) from the VoIP packet payload (voice frame), ii) apply a specific shrinking mechanism on the voice frame to produce S-F voice frame (as discussed below), iii) store the value (0 or 1) and place (start or end) of shrunk bits to be restored at the R-ITTP-PS entity (as discussed below), iv) and reattach the VoIP packet header (ITTP/IP) to the S-F voice frame. Finally, the VoIP packet is sent to the receiver's VoIP gateway. Fig. 3 demonstrates the S-ITTP-PS entity functions.

The purpose of the shrinking mechanism is to lessen the voice frame size. There are several operations performed by the shrinking mechanism to lessen the voice frame size and produce S-F voice frame. First, check whether the value of the leading bit one or zero. Second, regardless of whether the leading bit is one or zero, determine the total number of leading bits till the bit with the opposite value of the leading bit. Third, save the number of leading bits in the leading counter (L-count). Fourth, check whether the value of the trailing bit one or zero. Fifth, regardless of whether the trailing bit is one or zero, determine the total number of trailing bits till the bit with the opposite value of the trailing bit. Sixth, save the number of trailing bits in the trailing counter (T-count). Seventh, compare the L-count and T-count. If the L-count greater than or equal the T-count removes the leading bits, otherwise remove the trailing bits. These operations produce the S-F voice frame. The examples in Table II demonstrate the voice frame shrinking process at the S-ITTP-PS entity. Notably, the values of the voice frame in Table II are not real and are only for demonstration purposes.

As mentioned previously, the value (0 or 1) and place (start or end) of shrunk bits must be stored and sent to the R-ITTP-PS entity to restore the O-F voice frame. To achieve that, the ITTP-PS method will reemploy the flag bits in the IP protocol header. The three flag bits in the IP protocol header are used to control and identify fragments of the packet (if any). In the case of VoIP, the packets are not fragmented because they are typically very small, between 36-bytes to 56-bytes, when using ITTP protocol. Thus, the three flag bits are always set to zero in the case of VoIP packets. Accordingly, the S-ITTP-PS entity will use them to denote the value and place of the eliminated bits from the voice frame. Only four possibilities are needed to denote the value and place of the eliminated bits, thus, the shrinking mechanism will use only the first two bits (4 values) of the flag bits. The denotation of four values is as follows: 00 denotes shrinking the leading zeros, 01 denotes shrinking the leading ones, 10 denotes shrinking the trailing zeros, 11 denotes shrinking the trailing ones.

B. R-ITTP-PS Entity Functions

The R-ITTP-PS entity performs four main functions to restore the S-F voice frame to its original form (O-F frame form). First, detach the VoIP packet header (ITTP/IP) from the VoIP packet payload (voice frame). Second, apply the shrinking mechanism on the voice frame to restore the S-F voice frame to the O-F voice frame (as discussed below). Third, the flag bits in the IP protocol header are set to zero to avoid misinterpretation at the receiver client. Fourth, reattach the VoIP packet header (ITTP/IP) to the O-F voice frame and send the VoIP packet to its destination. Fig. 4 demonstrates the R-ITTP-PS entity functions.

The purpose of the shrinking mechanism at the receiver end VoIP gateway is to restore the S-F voice frame to the O-F voice frame. There are two main operations performed by the shrinking mechanism to achieve this purpose. First, find the number (n) of shrunk bits from the O-F voice frame by S-ITTP-PS entity at the sender end VoIP gateway (n= O-F length – S-F length). Second, restore the S-F voice frame to O-F voice frame based on the value of the flag fields of the IP protocol header. The denotation of the flag fields is as follows: 00 denotes append n zeros at the beginning of S-F voice frame, 01 append n ones at the beginning of S-F voice frame, 10 denotes append n zeros at the end of S-F voice frame, 11 denotes append n ones at the end of S-F voice frame. The examples in Table III demonstrate the restoration of the S-F frame to the O-F frame by the R-ITTP-PS entity. These examples are the same examples in Table II.

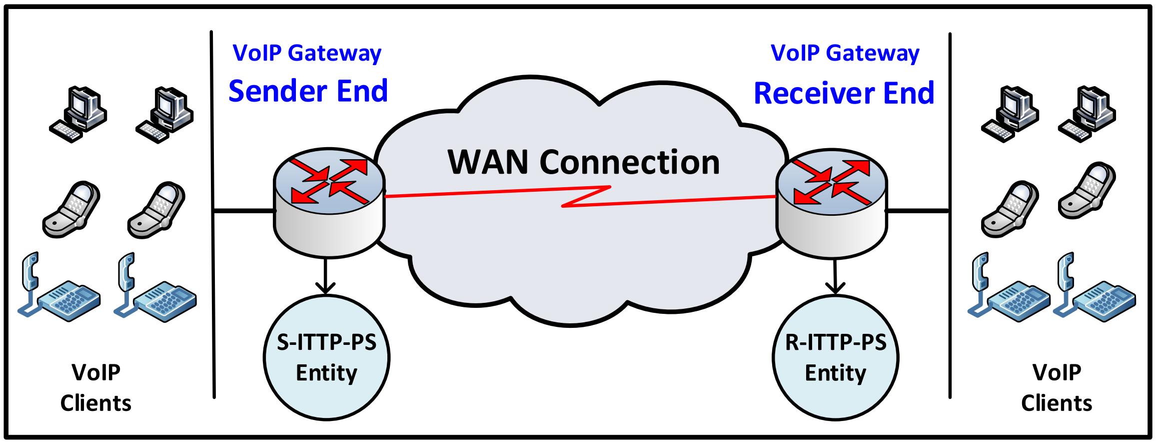

Fig. 2. Location of ITTP-PS Method's Entities.

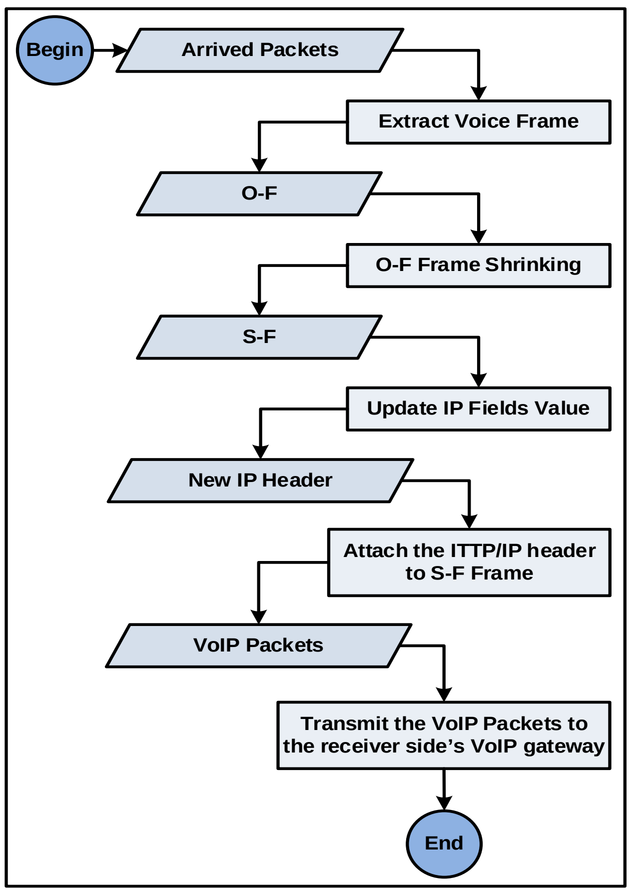

Fig. 3. S-ITTP-PS Entity Functions.

TABLE II. EXAMPLES OF SHRINKING THE VOICE FRAME

O-F Frame	L-Count	T-Count	Action	S-F Frame
000001100010100110000	5	4	Shrink the leading zeros because of L-Count is greater than T-Count.	1100010100110000
000110011110011100000	3	5	Shrink the trailing zeros because of T-count is greater than L-Count.	0001100111100111
000000100111001101111	6	4	Shrink the leading zeros because of L-Count is greater than T-Count.	100111001101111
111111010010111110000	6	4	Shrink the leading ones because of L-Count is greater than T-Count.	010010111110000
111110110110111111111	5	9	Shrink the trailing ones because of T-Count is greater than L-Count.	111110110110

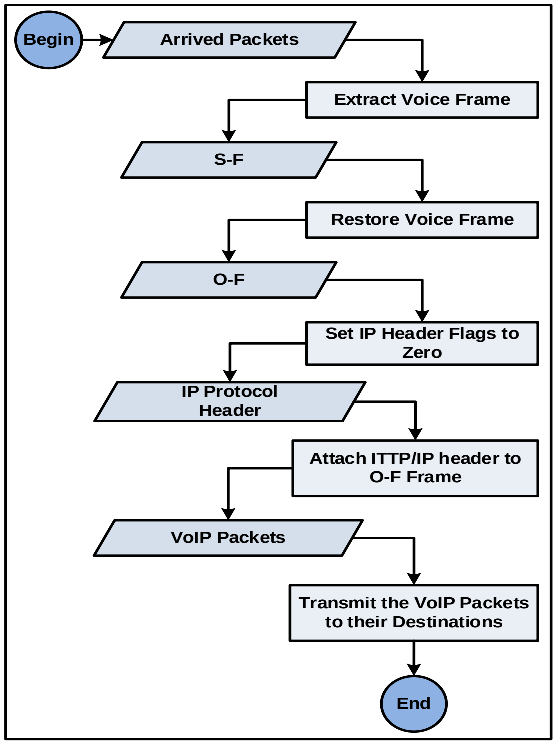

Fig. 4. R-ITTP-PS Entity Functions.

TABLE III. EXAMPLES OF RESTORING THE S-F RAME TO O-F FRAME

S-F Frame	Flag Field Value	Action	O-F Frame
1100010100110000	00	Append n zeros at beginning of the S-F voice frame.	00000110001010011000O
0001100111100111	10	Append n zeros at end of the S-F voice frame.	00011001111001110000O
100111001101111	00	Append n zeros at beginning of the S-F voice frame.	00000010011100110111 1
010010111110000	10	Append n ones at beginning of the S-F voice frame.	11111010010111110000
111110110110	11	Append n ones at end of the S-F voice frame.	11111011011011111111 1

IV. THE PROPESED ITTP-PS METHOD PERFORMANCE EVALUATION

This section discusses the ITTP-PS method's bandwidth exploitation in comparison with traditional ITTP protocol without shrinking the voice frame. The bandwidth exploitation was evaluated based on two different elements, namely, voice frame shrinking ratio (FRR) and isochronous calls capacity. For the evaluation to be sensible, three different VoIP codecs (LPC, G.723.1, and G.729) will be used to investigate these two elements.

A. *Frame Shrinkig Ratio (FRR)*

This subsection investigates the ITTP-PS method's FRR ratio. The FRR is the number of shrunk bits from the voice frame to the total number of bits of the voice frame without shrinking. The higher the number of shrunk bits the better the bandwidth exploitation. The FRR ratio has been investigated with ten different calls. The average FRR ratio of 20 VoIP packets of each call has been calculated separately. Fig. 5 displays the FRR of the LPC codec. The FRR ratio of the LPC codec has reached around between 12.5% and 18.5%. Fig. 6 displays the FRR of the G.723.1 codec. The FRR ratio of the G.723.1codec has reached around between 10% and 20%. Fig. 7 displays the FRR of the G.729 codec. The FRR ratio of the G.729 codec has reached around between 7% and 15.5%. Accordingly, the ITTP-PS method accomplished a noticeable bandwidth exploitation in comparison with the traditional voice frame without shrinking. Thus, the ITTP-PS method achieved it main objective of improving VoIP network bandwidth use. The three codecs accomplish different FRR ratio because the pattern of the voice frame of each codec is different.

B. *Isochronous Calls Capacity*

This subsection investigates the proposed ITTP-PS method isochronous calls capacity improvement ratio. The bandwidth exploitation improvement ratio was investigated then the isochronous calls capacity improvement ratio will have similar values. The bandwidth exploitation improvement ratio has been investigated with 10 different calls. The average bandwidth exploitation improvement ratio of 20 VoIP packets of each call has been calculated separately. Fig. 8 displays the bandwidth exploitation improvement ratio of the LPC codec. The bandwidth exploitation improvement ratio of the LPC codec has reached around between 4.5% and 6.5%. Fig. 9 displays the bandwidth exploitation improvement ratio of the

G.723.1 codec. The bandwidth exploitation improvement ratio of the G.723.1codec has reached around between 5% and 9.5%. Fig. 10 displays the bandwidth exploitation improvement ratio of the G.729 codec. The bandwidth exploitation improvement ratio of the G.729 codec has reached around between 2% and 4.5%. Therefore, the isochronous calls capacity improvement ratio will have similar values. Accordingly, the ITTP-PS method accomplished a pretty good isochronous calls capacity improvement ratio in comparison with the traditional voice frame without shrinking. Thus, the ITTP-PS method achieved it main objective of improving VoIP network bandwidth use. Obviously, this feature is due to the shrinking the voice frame. The three codecs accomplish different isochronous calls capacity improvement ratio because the pattern of the voice frame of each codec is different.

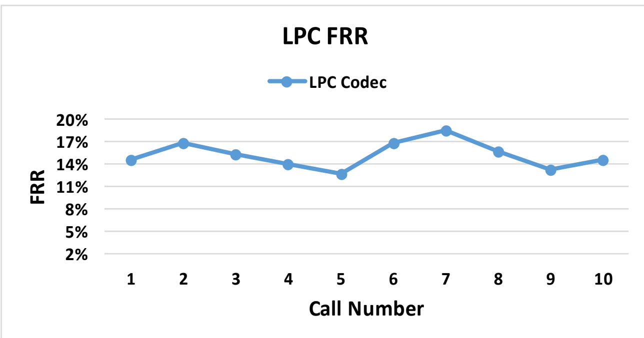

Fig. 5. FRR of the LPC Codec.

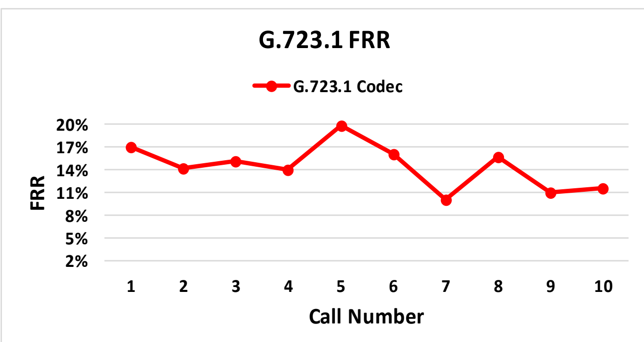

Fig. 6. FRR of the G.723.1 Codec.

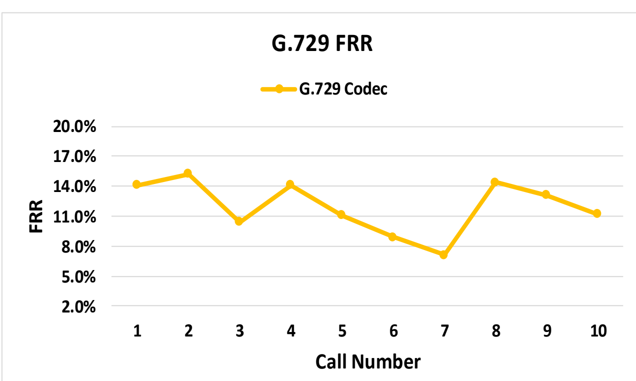

Fig. 7. FRR of the G.729 Codec.

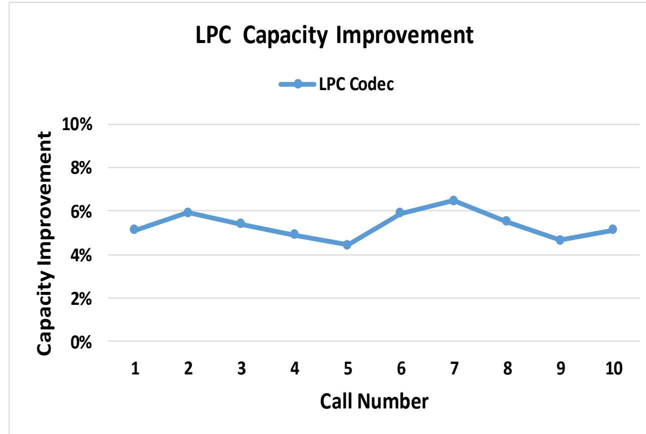

Fig. 8. Isochronous Calls Capacity Improvement Ratio of the LPC Codec.

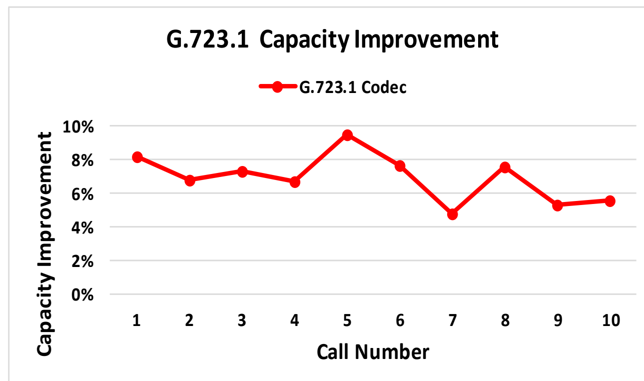

Fig. 9. Isochronous Calls Capacity Improvement Ratio of the G.7321.1 Codec.

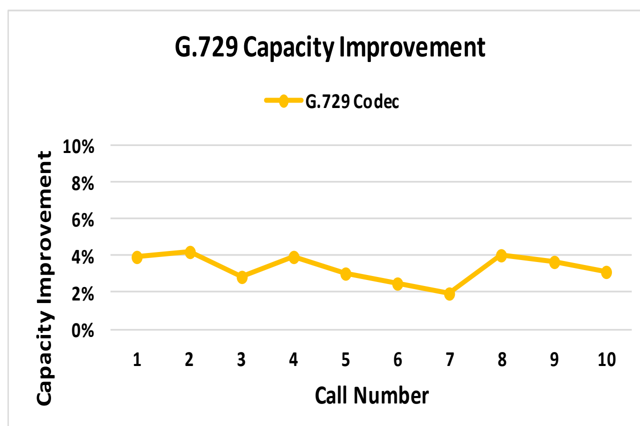

Fig. 10. FIsochronous Calls Capacity Improvement Ratio of the G.729 Codec.

V. Conclusion

VoIP has been widely adopted by private and public sectors replacing the traditional telecommunication systems. Nevertheless, VoIP faces a serious bandwidth exploitation inefficiency problem. This article has proposed a new method, called ITTP-PS, to alleviate this problem. The main idea of the proposed ITTP-PS method is to shrink the VoIP packet payload, based on certain mechanism. The ITTP-PS method has been deployed at the VoIP gateway that is connected to the WAN connection. The sender side VoIP gateway performs VoIP packet payload shrinking using the S-ITTP-PS entity of the ITTP-PS method. The receiver side VoIP gateway restores the VoIP packet payload to its normal size using the R-ITTP-PS entity of the ITTP-PS method. The R-ITTP-PS entity achieves that by utilizing the flag bits in the IP protocol header. The ITTP-PS method has been implemented and compared with traditional ITTP protocol without shrinking the VoIP packet payload. The VoIP packet payload shrinking ratio has been enhanced by up to around 20% in the tested cases with the G.723.1 codec. In addition, the isochronous calls capacity improvement ratio has been enhanced by up to around 9.5% in the tested cases with the same codec. Eventually, the ITTP-PS has been alleviated the bandwidth exploitation inefficiency problem of VoIP applications. In the future, the proposed ITTP-PS method will be evaluated with different VoIP codecs to gain a more realistic evaluation. In addition, the ITTP-PS method will be combined with other approaches of bandwidth exploitation such as VoIP packet multiplexing.

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Development and Analysis of a Zeta Method for Low-Cost, Camera-based Iris Recognition

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***Abstract*—Iris recognition is an alternative authentication method. Many studies have tried to improve iris recognition as a biometric-based alternative for secure authentication. Iris segmentation is an important part of iris recognition because it defines the image region that is used for subsequent processing such as feature extraction and matching, hence directly affects the overall iris recognition performance. This work focuses on the development of an authentication system using localization methods and half-polar normalization of the iris. The proposed Zeta method uses a new model of eye segmentation and normalization that can be used simultaneously on both eyes, considering different iris patterns in those two eyes. There are seven variants of the proposed and tested Zeta method: Zeta-v1, Zeta-v2, Zeta-v3, Zeta-v4, Zeta-v5, Zeta-v6, and Zeta-v7. Overall, the method achieved an average segmentation time performance of 0.0138427 seconds. The most accurate rate was by the Zeta-v1 method, with a value threshold of 100% on the wrong rejection rate and 94.9% on the correct acceptance rate.**

Keywords—Iris recognition; iris segmentation; Zeta; authentication; biometric; pattern recognition

I. Introduction

The biological characteristics of humans are widely used for security and authentication purposes. One of the most used body parts, due to its accuracy, is the eyes. In 1987, although they had not yet acquired the implementation methods, Leonard Flom and Alan Safir received patents for the use of eyes for bio-metric purposes [1]. In 1994, John Daugman successfully implemented this idea by using the iris, a method later called iris recognition [2].

After an image of the eyes has been acquired, there are five stages performed in the iris-recognition process: (1) iris and pupil localization, (2) iris segmentation, (3) normalization, (4) encoding, and (5) pattern matching [3]. Based on our previous work, the iris segmentation stage is the most resource-consuming stage yet is the most critical process to determine the result of iris recognition [4]. The iris segmentation stage influences the accuracy of the system since the threshold of pattern matching is affected by how much of the iris area is processed, which is determined in this stage.

To acquire better performance and accuracy in iris recognition using a modified low-cost camera, our previous studies proved that half-polar iris localization and normalization methods could be implemented in our modified low-cost camera [4]. Half-polar iris localization uses parts of the eyes where eyelashes and eyelids do not interfere in distinguishing the border of the iris and sclera.

In the biometric system, there are several things that must be fulfilled, namely accuracy, speed, and resource requirements, be harmless to the users, be accepted by the intended population, and be sufficiently robust to various fraudulent methods and attacks to the system [5]. In this work, we focused on improving of the half-polar iris segmentation method to enhance the performance of iris recognition that uses a modified low-cost camera. We propose Zeta iris segmentation, separated into seven unique segmentation methods to get the best segmentation in terms of accuracy and speed. The performance of each segmentation method was determined and then evaluated based on the level of accuracy and execution time.

The dataset from CASIA-IrisV1, introduced by the Chinese Academy of Sciences Institute of Automation in 2006, was used to conduct the test for the proposed method. CASIA-IrisV1 contains 756 iris images from 108 subjects. For each eye, 7 images are captured in two sessions with a homemade iris camera, where three samples are collected in the first session and four in the second session. The database contains the left eye and right eye. All images are stored as BMP format with resolution 320 * 280.

The remainder of this paper is organized as follows: In Section 2, introduces the related work of iris segmentation including deep-learning-based algorithm. Development of iris recognition in both eyes and describes some methods of localization and normalization that we propose are given in Section 3. In Section 4, the experiment results and analysis are described in detail. In Section 5, we present the conclusions.

II. Related Works

Iris recognition is commonly used for individual identification, with an accuracy range between 90 and 99 percent [6]. In general, there are trade-offs between the accuracy and speed of iris recognition. A more accurate method takes more processing time. In contrast, a seamless process with fast processing time tends to become less accurate. There are various algorithms and methodologies proposed to identify iris similarities. In this work we would like to focus on the methodologies for iris segmentation that become critical determinants during iris recognition.

Shah et al. proposed iris segmentation based on geodesic active contours [7]. Geodesic active contours segments based on the boundary of the iris. To determine the boundary of the segmented iris, this method does not use an approximated circle. Based on the active contours, the result of segmentation

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will produce adaptive output while considering surrounding distractions. This method is good for iris detection from different angles of view. However, because active contours are dynamic, the output may be inconsistent. Moreover, the process to determine active contours requires more processing time.

He et al. proposed an iris recognition process inspired by Daugman segmentation [8]. Basically, this method proposes four steps: noise removal, pupil localization, eyelid localization, and eyelash and shadow detection. The output of the segmentation is a segmented iris image with removed noise. This method has good accuracy with the proposed noise removal. However, this high accuracy still takes more processing time.

Kong et al. proposed noise detection before iris segmentation [9]. The main noises are eyelids, eyelashes, and reflections. Huang et al. also proposed iris segmentation based on iris noise removal, this work also focused on the removal of noise from eyelashes, eyelids, reflections and pupils. To remove the noises, this work proposed a fusion of the edge and region [10].

Recent iris segmentation research has proposed implementation of machine learning to increase the accuracy of iris segmentation. More and more researchers apply deep learning to iris image segmentation [11] [12][13][14][15] [16]. CNN can be used to segment the iris image, which reduces the process of feature extraction and selection, and further improve the final accuracy [17].

Arsalan et al. focused on the challenge of blur, glint, image occlusion, and low resolution. These challenges from an image may bring less accuracy in iris recognition. To address these challenges, this work proposed a convolutional network to segment an iris [18]. Tobji et al. also proposed iris segmentation based on a fully convolutional network. The objective of the work was on the challenge of different image resolutions [19]. By implementing a convolutional network those works could increase their iris segmentation accuracy. However, in general the processing time was high due to the computation process of the neural network.

Compared to others research, our work aims to create fast iris recognition by a proposed determined zone for iris segmentation. By varying the selected iris segments, this method will produce a variation of accuracy and processing times. We aim to get optimum accuracy and processing time for iris segmentation.

III. Methodology

This section explains the development of iris recognition in a single eye to iris recognition in both eyes and describes some methods of localization and normalization that we propose. We separated section three into two parts. The first is the hardware material that we used to perform the experiments. The second is the methodology to run the experiments.

A. Camera Hardware Design

Cameras commonly used today are usually capable of capturing ultraviolet and infrared (IR) rays. However, these two rays, which cannot be seen by humans, do not enter the camera sensor because it is filtered. PS3 eye cameras are customized by removing the IR filter and replacing it with a lens without an IR filter so that the camera can capture black and white images. The customization of the PS3 camera and the captured images is shown in Fig. 1 and the IR LEDs are arranged in parallel and placed in front of the lens, as shown in Fig. 2.

In this work, we used a PS3 eye camera with a resolution capability of 640 × 480 pixels. The reason we chose this camera was that the resolution was sufficient to perform iris recognition at a considerably lower price with appropriate image quality. Compared to our previous work, this work improved by implementing double cameras to recognize both eyes in parallel.

B. Iris Recognition Process

a) Acquisition of eye images: In eye image acquisition, there are several requirements for the hardware. The iris scanner must be used without an IR filter. So, we removed the IR filter from the camera. Then to strengthen the IR light, we mounted IR LEDs on the camera. After the camera hardware is ready, the image can be taken. The resulting image should be clear. The eye parts, such as pupils, the iris, sclera, and eyelids, must be visible. To get clear results, the scanner camera must have high resolution, high acuity, and appropriate lighting conditions

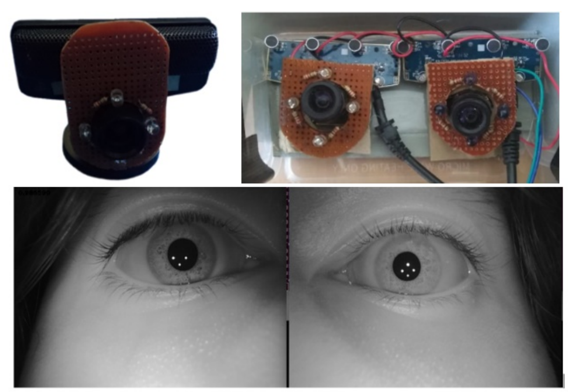

Fig. 1. Customized PS3 Camera with IR LEDs. Single and Double Camera and Captured Image Result from a Double Camera.

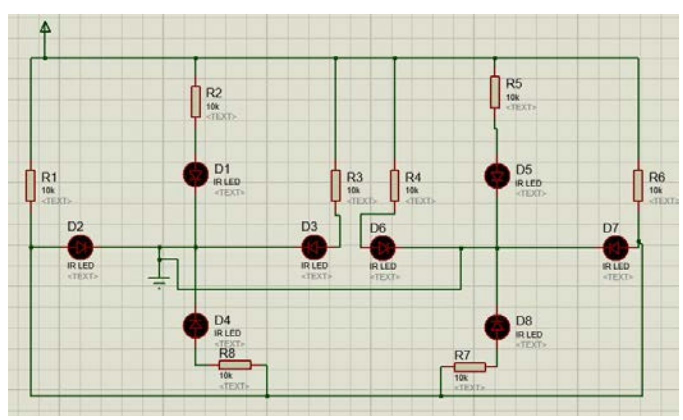

Fig. 2. IR LED Design Schematic for Two Cameras. The IR LEDs are Arranged in Parallel and Placed in Front of the Lens.

b) Iris localization; Iris segmentation and localization are two different methods. Localization is a method for finding and isolating the iris in digital images, while segmentation is a method for selecting certain iris sections to be used for iris pattern matching. In localization and segmentation, there are several processes. The first process is obtaining the image processing kernel, which is a small matrix used for image processing (Fig. 3). This kernel is useful for determining the edges of images, smoothing images, and sharpening them.

The second process is color inversion. This process aims to make the image color negative. This function can be performed easily because the colors used in an IR unfiltered contain only three primary colors: black, white, and gray. To get a negative from the image, inverse black into white and vice versa.

The third process is Gaussian smoothing, a method to smooth the image. A smooth image is obtained by combining the kernel with this Gaussian method. Mathematically, the Gaussian smoothing function is shown in equation 1.

$$g(x,y) = \frac{1}{2\pi\sigma^2} e^{\frac{-(x^2+y^2)}{2\pi r}} \tag{1}$$

The fourth process is localization of the pupil by utilizing the results of the blurring process. After blurring is done, the contour of the received image is found. Several steps must be passed to get the center of the eye. In this case, the pupil becomes a reference to find the location of the iris. Localization of the iris is performed after the pupil location is obtained. We can find the iris by making the pupil become the center point of polar coordinates. The method used to make the pupil become the center point is image transformation, then line transformation is used to find the boundary between the sclera and the iris. This method allows us to obtain maximum results because it only uses values of -30° to 30° and 150° to 210°, where the angle is the side of the human eye not disturbed by the eyelashes and eyelids. Fig. 4 shows the process of getting the location of the iris.

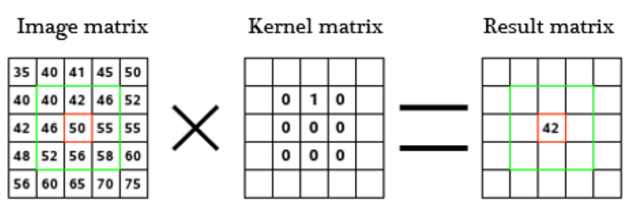

Fig. 3. Image Matrix Convolution Process with a Kernel Matrix.

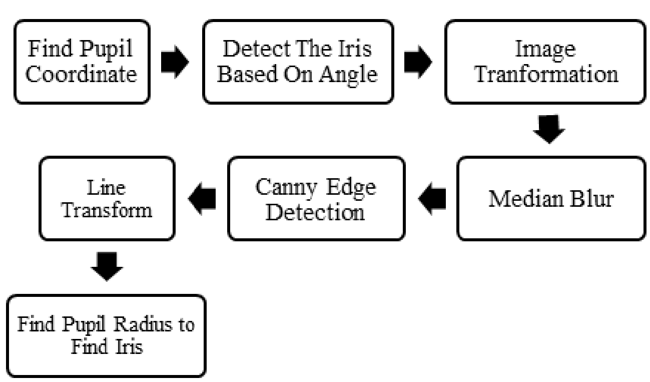

Fig. 4. Iris Localization Process.

c) Iris segmentation and normalization: Segmentation is the cutting of a specific part of the iris for normalization. This is because not all iris portions are visible in a digital image from the resulting image. In this work, we propose iris segmentation variations by picking a different area of the iris before the normalization process. The area selection also considers disturbances around the iris, such as eyelids and eyelashes. Fig. 5 shows the variance of iris segmentation from half-polar, Zeta-v1, Zeta-v2, Zeta-v3, Zeta-v4, Zeta-v5, Zeta-v6, and Zeta-7.

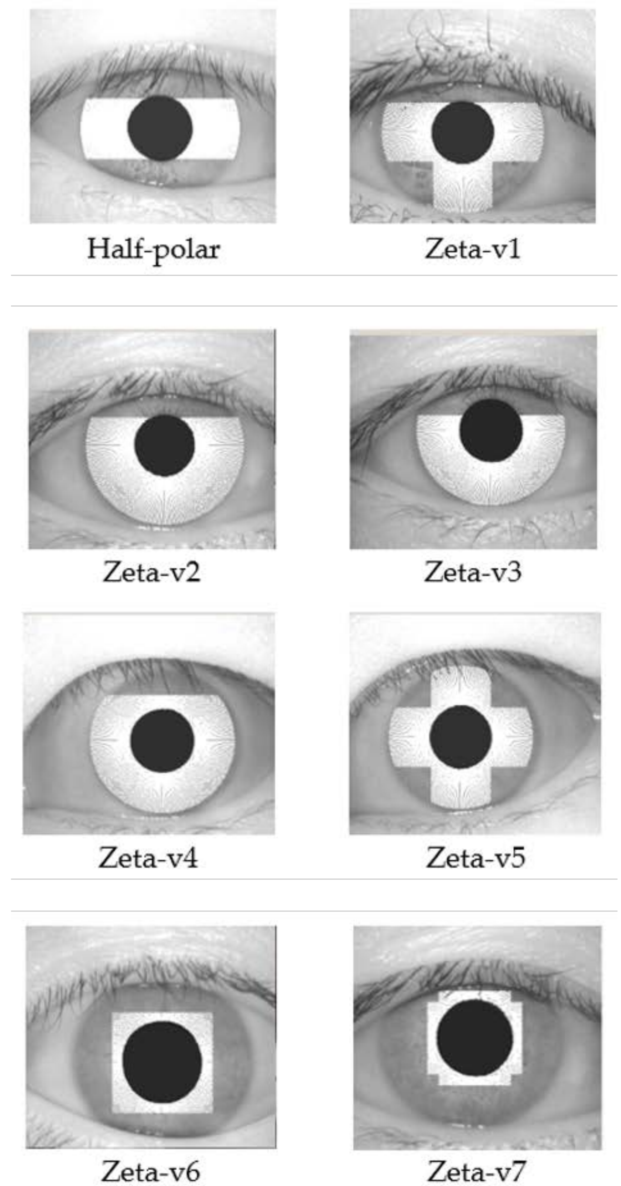

Fig. 5. Proposed Zeta Iris Segmentation.

Normalization aims to eliminate or update existing anomalies. In this work, we used the Daugman rubber sheet model to normalize a special image of a circle—like an iris—and make it square. In Fig. 5, we can see the segmentation results of the half-polar segmentation method and the seven versions of the Zeta method. In the Daugman rubber sheet model, the iris is mapped to the polar coordinate (r, θ), where θ starts from 0 to 359 with the same radius at each starting point, to form a full circle [20]. A polar coordinate map is obtained using equations 2 and 3:

$$f(r) = x_c + \left((rp + r)\cos\theta\right) \tag{2}$$

$$f(\theta) = y_c + \left((rp + r)\sin\theta\right) \tag{3}$$

where rp is the radius of the pupil, r represents the iris radius, with θ being the turning angle. Fig. 6 shows the process of the rubber sheet model.

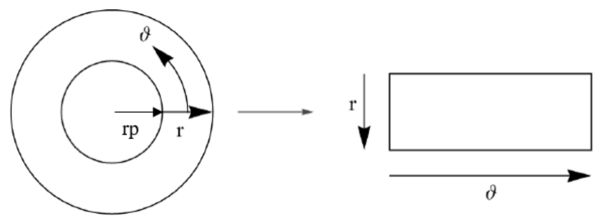

Fig. 6. Daugman Rubber Sheet Model.

d) Encoding: Iris encoding is used to change the image of the iris that has gone through the normalization process into a binary code form. The binary code obtained is the result of encoding features found on iris patterns extracted using the Gabor filter, a method offered by Daugman [21]. The disadvantage of the Gabor filter is the presence of a DC component when the bandwidth is higher than an octave (Field, 1987). However, a zero-value DC component can be obtained from any bandwidth by using a Gabor filter Gaussian in a logarithmic scale, called a log-Gabor filter [22].

The log-Gabor filter is a linear filter used to extract features from digital image data. These features can be textures or patterns. The way it worked was that the first iris image that was normalized was split into lines so that there was a one-dimensional image of the row number of the image by changing the function from a time domain into a frequency domain using Fourier transform. It was then convolved with a self-defined log-Gabor kernel with equation 4:

$$G(f) = exp\left(\frac{-\left(log\left(f/_{f_0}\right)\right)^2}{2\left(log\left(\sigma/_{f_0}\right)\right)^2}\right) \tag{4}$$

where f0 is the frequency in the middle, and σ affects the bandwidth of the filter or the existing kernel. f is worth {0, ..., 0.5} number of convolution image columns, f_0 is worth 18, and σ is 0.5 [22].

The phase of each image is shown in Fig. 7, which maps the binary code according to phase. The phase determination was compared to the amplitude, then analyzed because this amplitude value was highly dependent on external factors, for example, the illumination and contrast levels of the image [21]. An amplitude value close to 0 was ignored by changing the mask value to 1 [22]. The resulting binary code's length was twice its width. The following figures are the results of encoding in the small box method and the resulting mask.

Fig. 8 shows the mask code of Zeta-v1 iris segmentation, and Fig. 9 shows the iris code.

e) Pattern matching: Iris pattern matching compared the similarity of two iris binary codes by using the Hamming distance method's calculation. The use of Hamming distance is based on performance indicated after testing several different distance metrics. Of Euclidean distance, Hamming distance, and dZ distance, Hamming distance shows the best accuracy—average performance reaches 99.6% [23]. Therefore, Hamming distance is the most popular metric distance for iris matching [24] [25]. The Hamming distance equation is shown in equation 5.

$$HD = \frac{\sum_{n=1}^{N}(m_{1n}(NOR)m_{2n})(AND)(i_{1n}(XOR)i_{2n})}{N - \sum_{n=1}^{N} m_{1n}(OR)m_{2n}} \tag{5}$$

In equation 5, i_1 and i_2 are two bit-wise binary code templates to be compared. Noise mask, which is also in binary template form, is represented by m_{1n} and m_{2n}. N is the bit which is represented by each template. Fig. 10 shows the complete process of the iris recognition system.

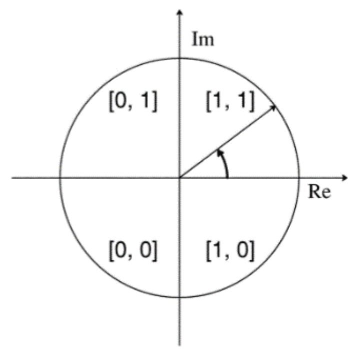

Fig. 7. Binary Code Mapping According to Phase.

Fig. 8. Mask Code of Zeta-v1 Iris Segmentation.

Fig. 9. Iris Code of Zeta-v1 Iris Segmentation.

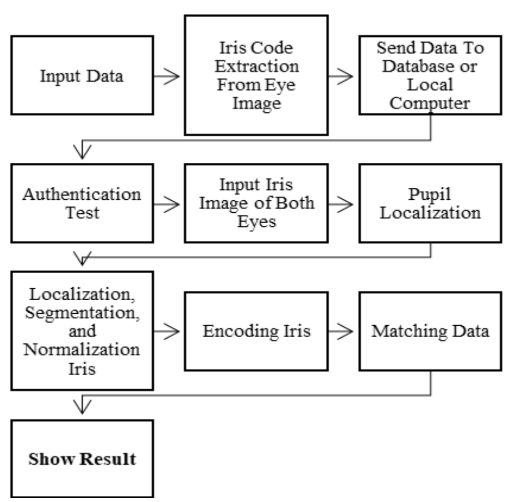

Fig. 10. Flow Process from Iris Recognition.

IV. Results and Discussion

This section explains experimental result of the development of iris recognition in a single eye to iris recognition in both eyes.

A. Runtime Execution

In this work, the CASIA-IrisV1 dataset was used. The dataset is 108 images of the human iris. There are seven images of each iris: three from the first session and four from the second session. This experiment did not use all parts of the dataset but used a sample of 20 eye images that produced 120 iris codes for each type of localization and normalization. The programs were tested on computers with the following specifications: Intel Core i5 4200U processor, 4GB RAM, Ubuntu Operating System 16.04 lts, and OpenCV version 4.0.0.

A performance comparison for all segmentation methods is depicted in Fig. 11. The best performance was obtained by the Zeta-v7 method. This method encodes code more simply, thus making it work faster than the other methods. Although the minimum execution time of Zeta-v6 segmentation was lower than Zeta-v7, the maximum and average performance of Zeta-v7 was better than Zeta-v6. The average of Zeta-v7 was ±72 times iris matching in one second while Zeta-v6 was ±71.97. The half-polar method came third after Zeta-v7 and Zeta-v6. This shows that Zeta-v6 and Zeta-v7 methods are the best choices for overall system performance development.

B. Hamming Distance and Accuracy

The accuracy test conducted in this work was based on a dataset from CASIA-IrisV1. The objective of performing this test was to find the maximum and minimum threshold value to get the best iris recognition accuracy. In our previous work for half-polar segmentation, the Hamming distance 0.42 became the threshold for acceptance. A Hamming distance of more than 0.42 was rejected for not matching and was considered as an iris from a different eye. Otherwise, two irises with a Hamming distance less than 0.42 were accepted and determined as an iris from the same eye. To find the best accuracy we can alternate the Hamming distance value during the experiments.

From the CASIA-IrisV1 there are 72 iris data from different people. Each person is represented by three iris images. Overall there are 216 iris images from 72 people. With this data we ran eight different methods of iris segmentation. From the experiment we got a total Hamming distance value of 1,728. Based on this value, we determined the acceptance threshold of the Hamming distance. We also combined the data with our own iris dataset. We collected 20 sets of Zeta iris data from different eyes. We then compared these 1140 times with non-matching iris data. By comparing it with the wrong dataset, the results should be rejected. We defined the rejection of wrong iris data as the rejection rate. To find the optimum rejection rate, we also performed an adjustment on the Hamming distance value. To find the optimum performance of the Hamming distance, we determined the crossing value between the optimum acceptance and rejection rates. For example, as shown in Fig. 12, we obtained the optimum Hamming distance of 0.455. This value was obtained when the acceptance rate of correct data and rejection rate of wrong data both reached 98%. According to the experiment, we determined that 0.455 was the best Hamming distance to obtain correct data acceptance and wrong data rejection during iris comparison. However, it is also possible to determine the optimum Hamming distance based on the threshold of the wrong rejection rate and correct acceptance rate. In this work we focused on a threshold of 100% wrong rejection rate to prevent a false positive result. After eliminating the false positive we continued to minimize false negative outcomes by adjusting the threshold of correct acceptance rate to obtain the optimum Hamming distance.

The accuracy analysis of pupil localization and iris localization was performed using the CASIA-IrisV1 dataset. A total of 324 images were tested on each system function. The tested images consisted of 108 eye images taken in the first session, which is as much as three images for each eye. The localization function was a basic key to the accuracy of the Hamming distance data.

The pupil localization must succeed to proceed to the next process of iris localization. This localization was done by finding contours on the image of the treated eye image. The table below illustrates the results of manually manipulated localization experiments on the 324 eye images of the existing dataset. Table I shows the accuracy of pupil and iris localization of the dataset. Iris localization must be successful to obtain the right results for comparison.

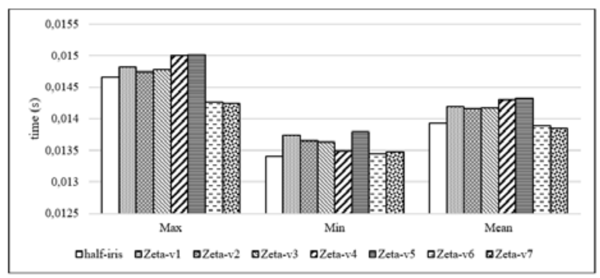

Fig. 11. Iris Segmentation Runtime Comparison: Maximum, Minimum, and Mean.

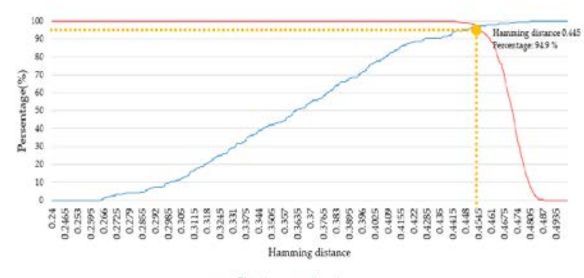

Fig. 12. Cross Section between Acceptance Rate and Rejection Rate to Determined Hamming Distance.

TABLE I. Table of Pupil and Iris Localization Accuracy

Object	Localization success	Localization Fail	Total	Accuracy
Pupil	324	0	324	100%
Iris	310	14	324	95.68%

The calculation results in Table I were one of the measurements of success in iris segmentation and Hamming distance calculation. This section excluded pupil localization because the pupil localization accuracy had already reached 100%. This experiment used eight iris segmentation methods as independent variables. The dependent variable was the performance of iris code matching time and the resulting Hamming distance value. The control variable was the CASIA-IrisV1 dataset, which took the iris code of 72 different people, and each person had three iris codes from the first capture in the dataset. To calculate the accuracy of each segmentation, equation 6 was used.

$$Accuracy = 100 - \frac{fail\ attempt\ x\ 100}{total\ data} \quad (6)$$

From the experiment results, we obtained the table of maximum, minimum, and average Hamming distance for the reception, shown in Fig. 13. The average value and minimum value of Hamming distance using the Zeta-v7 segmentation method was the smallest while the maximum value did not show a significant difference between methods. The average value of Hamming distance from the Zeta-v7 segmentation method was 0.350347. In one second, 72.2 times iris matching was applied when using the Zeta-v7 segmentation method.

Based on the rejection and acceptance values, Zeta-v1 is the method with the highest percentage of accuracy, 94.90%. In Table II, we can see Zeta-v1 and Zeta-v5 segmentation had the highest value when using Hamming distance limits taken at the wrong rejection rate of 100%.

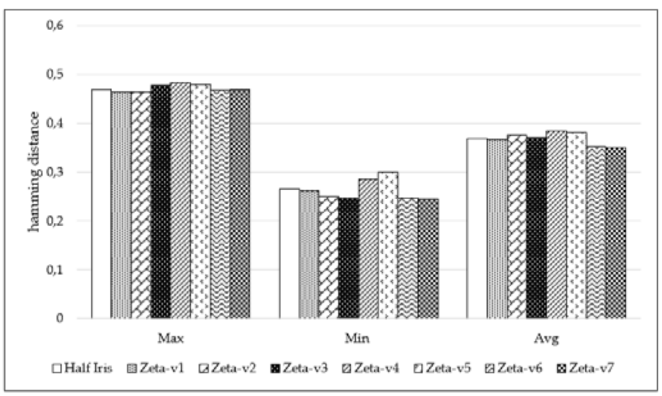

Fig. 13. Hamming Distance Value of Minimum, Maximum, and Average Compared.

TABLE II. ACCURACY TABLE WITH 100% WRONG REJECTION

No	Method name	Hamming distance	Accuracy
1	Half-polar	0.437	90.17%
2	Zeta-v1	0.445	94.90%
3	Zeta-v2	0.437	90.74%
4	Zeta-v3	0.421	83.79%
5	Zeta-v4	0.424	81.01%
6	Zeta-v5	0.451	93.98%
7	Zeta-v6	0.427	90.27%
8	Zeta-v7	0.427	90.29%

Table II shows the data when the wrong rejection rate is 100%. This means the rejection has a tolerance of 100% less than the value of the denial percentage in the segmentation. In Table III, the Zeta-v2 method shows the largest percentage of accuracy—98.24%, with an incorrect acceptance tolerance of 1.76%. The second highest percentage is shown by the Zeta-v5 method—97.01%, with a tolerance of 2.99%. In Table III, we can see that the decreasing percentage of the smaller the value of Hamming distance used as a threshold. The best accuracy with the smallest Hamming distance value is shown by Zeta-v6 and Zeta-v7.

TABLE III. ACCURACY TABLE WITHOUT WRONG REJECTION

No	Method name	Hamming distance	Accuracy
1	Half-polar	0.454	96.49%
2	Zeta-v1	0.460	96.67%
3	Zeta-v2	0.458	98.24%
4	Zeta-v3	0.456	96.05%
5	Zeta-v4	0.449	94.56%
6	Zeta-v5	0.464	97.01%
7	Zeta-v6	0.450	94.29%
8	Zeta-v7	0.448	94.03%

TABLE IV. VARIATION OF HAMMING DISTANCE AT DIFFERENT ACCURACY LEVELS

Accuracy percentage	90%	80%	70%	60%
Half-polar	0.427	0.41	0.395	0.393
Zeta-v1	0.427	0.416	0.393	0.38
Zeta-v2	0.435	0.413	0.398	0.387
Zeta-v3	0.431	0.413	0.392	0.376
Zeta-v4	0.4405	0.421	0.406	0.395
Zeta-v5	0.435	0.416	0.406	0.391
Zeta-v6	0.427	0.396	0.379	0.363
Zeta-v7	0.4245	0.397	0.374	0.359

In Table IV we can see the accuracy at specific points and the Hamming distance values used in each method. Each iris code comparison used the same template so that the size or size of the obtained Hamming distance was related to the area of the segmented region. With the Zeta-v7 iris segmentation, we can see that the smallest Hamming distance value reached an accuracy of 60%. This means in Zeta-v7 the segmented area was smaller than the other methods.

V. CONCLUSIONS

Based on experiments running several proposed schemas for iris segmentation, we found iris segmentation method Zeta-v7 was the most effective for the execution. When we ran Zeta-v7 iris segmentation on 72 pairs of eyes from the dataset, 0.9936 seconds were required for the whole process. This means, on average, every execution only required 0.0138946 seconds.

From the perspective of accuracy, we found Zeta-v1 was the most effective when the wrong rejection rate was 100%. This method had a correct acceptance rate of 96.67%, with

3.33% tolerance. Zeta-v2 became the most accurate with less tolerance. Zeta-v2 reached a correct acceptance rate of 98.25% with a Hamming distance of 0.458. Zeta-v2 had wrong tolerance of 1.755%.

From the perspective of Hamming distance, it is possible to use a smaller Hamming distance value compared to the Hamming distance of half-polar iris recognition. Methods Zeta-v6 and Zeta-v7 had the lowest possible Hamming distance values, respectively 0.374 and 0.396 with 100% wrong rejection and an accuracy of correct acceptance between 70–80%.

With the implementation of double cameras we got better accuracy compared to a single camera. With the double cameras, the angle of view became more stable compared to a single camera. In a single camera, the angle of view could change during the image acquisition process. Moreover, double cameras increased the accuracy of iris recognition, by comparing two iris images.

In the future, we plan to explore new methods for non-ideal conditions and use several different databases to evaluate the proposed architecture, so that the iris segmentation system is not only designed based on good iris images in the same database. We would also like to implement it on embedded platform like Odroid and Raspberry Pi to make it ready-made module.

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Virtual Machine Escape in Cloud Computing Services

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***Abstract*—It's of axioms; every progress that is devised in the field of facilitating daily life through technology is matched by many complications in terms of the methods that led to the creation of these inventions and how to maintain their sustainability, consistency, and development. In digital world that became not only as axiom of its nature, but it is now one of the main inherent features that define digital technology. Whereas Major international companies are in a big race to produce the new development and invention of their products to be supplied to markets, and all of that should be conquered within not more than a year. The immersion in that big race has to be armed with patience and deep breath.**

***Keywords*—Cloud computing; virtual machine escape; cloud security; impact of VM escape; VM escape counter measures; VM escape nature**

I. Introduction

With virtualization world, that accelerating, competitive, and pervasive environment, you would be plagued and dominated by many restrictions and vectors in terms of acquisition of business solutions. Hence, it's effortless to build a compute of the given resources in virtualization atmosphere, in other word; we can build virtual storages, virtual CPU's, virtual memory, etc. as much as we need, where & when needed within minutes or seconds [1].

This steady, fast, exaggerated and easy increase in the nature of virtualization which is intrinsic characteristic of it compels us to dealing with a proxy-managed property.

However, in virtualization each step has been made could expose us to be in the middle of a mud. Yet, we could characterize virtualization as a muddy, very flabby, slimy texture of logical components (Virtual Machine, Hypervisor, O.S.), leading to be parachuted uncovered in a confrontation with that exaggerated sprawl/stretching Orbit [2].

With all of the above, it's uneasy to hold that emulated components of virtualization entity close enough together to be functioned, give rise to a notorious vulnerability in Virtual Machines.

As a result, emerging of a real threat of breaking out the Virtual Machine and establish a direct interaction with the hypervisor, or with the host operating system, or create communication with the hardware itself, is called Virtual Machine Escape [3].

II. Research Methodology

Although most of the threats and flaws identified in physical hardware of Data Center are the same in Virtual Data Centre and any researcher could effortlessly find many topics cover these threats and concerns of cloud computing. However, when we have decided to prepare this paper, we have identified a very important question related to the rarity of scientific topics covering VM Escape; which encouraged us to proceed with probing this type of threats and trying to neutralize its patterns and shapes it could has.

In this paper we have strived to trace every piece of information and evidence about VM Escape. This collected information has been cited from well-mannered scientific researches published in prominent data basis. Hereinafter, we shall go through scanning and analyzing various issues regarding Virtual Machine Escape, to provide an overview of the VM Escape threat. Yet, this paper could not represent the ideal solution to prevent or mitigate the threat. Nonetheless, it provides a general understanding of the VM Escape threat and how it could be avoided to maintain Business Continuity of cloud computing.

To recognize the threat clearly, one should have his bird's eye view of the Virtual Architecture on various level as shown in Fig. 1.

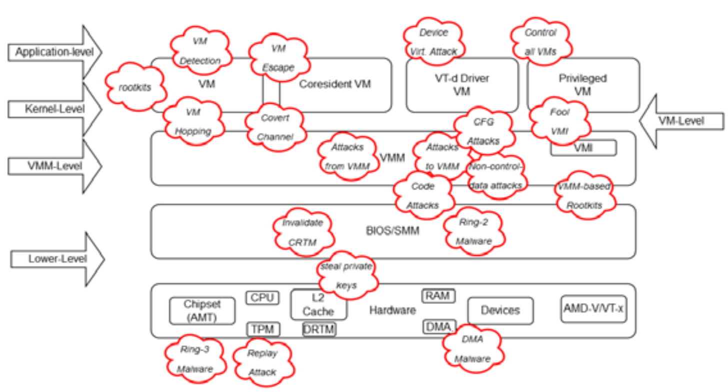

Fig. 1. Summary of some Attacks at the Various Levels [2].

III. Terminology

- Host: is a platform in virtualization environment running hypervisor software. All systems in virtualization run atop the platform of host hypervisor.
- VM, Virtual Machine, Virtual guest, usually called a Virtual Machine, is any system running the extracted environment which shall represent virtual model. Essentially, Virtual Machine is a group of files that exemplifies a hardware-based computing platform, is addition to configuration components, memory and storage altogether.
- Shared Folder: shared folders of malware that give permission to users to send/receive data between the non-virtualized system (Host) and a virtualized system (Guest).

IV. Virtual Architecture

- Traditionally, one operating system (OS) is deployed to each system (physical Hardware).
- Hypervisor is software authorizes multiple operating systems (OSs) to be run on hardware.
- As shown in Fig. 2, there are two types of Hypervisor:

1) Type 1 (Bare-metal hypervisor).
2) Type 2 (Hosted hypervisor).

- Virtual Machine: Virtual machine (VM) is a simulation of a computer system.
- There are three techniques of virtualizations as shown in Fig. 3; Full, Para, and Hardware Assisted Virtualization.

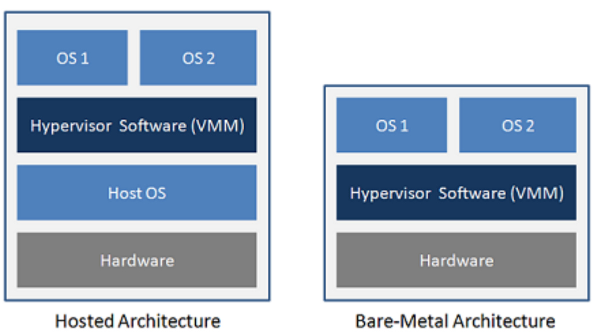

Fig. 2. Demonstration of Hypervisor Types [3].

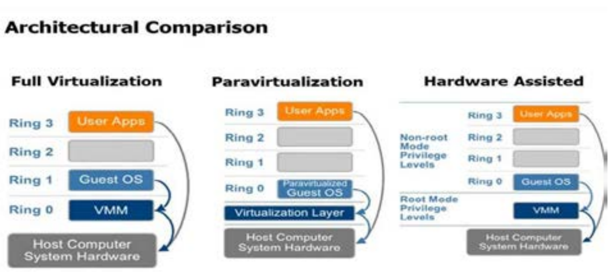

Fig. 3. Demonstration of the Virtualization Types [3].

V. History of VM Escape

A. Sand Table

Militarily, sand table is a method in which some of the military commanders who shall involve in attack or defense against the enemy use sands for modeling the friend and enemy forces; each commander has to demonstrate his predictions from the enemy's point of view, and how could the enemy uses the fragile points for potential attack.

B. Origin of VM Escape

In 2007, at Sansfire conference held in Washington DC, Tom Liston and Ed Skoudis (Senior Security Consultants) have demonstrated a concept of VM Escape. They have modeled several tools Highlighted that VM Escape might be occurred like VMchat, VMcat, VM Drag-n-Sploit and VMftp [4].

VI. VM Escape Nature

While the Hypervisor stands as barrier separating between the hardware resources and the Virtual Machines, offering a full isolation for the Virtual Machine, VM Escape is a compromise of the virtualization environment by an attacker who could exploit the virtual machine runs above the hypervisor. As a result, the VM Escapes from the isolation sphere. The possibility of such an attack is the attacker could run a code on a virtual machine, allowing an operating system running inside the hypervisor to be broken out and interact with it directly. This kind of attack might allow the attacker to have an access to the host operating system in addition to each virtual machines working on that host.

At Sansfire Conference experts were weighting that most of Virtual Machine Escape vulnerabilities are sourced to a type of Directory Traversal Attack [4].

There are number of Virtual machine escape types that may occur depending on the tools used to trigger Virtual Machine Escape attack [5], these tools are:

VMchat: It is plain chat software utilizes the VMware hypervisor communication channel as a backdoor to send messages between guest's operating systems exclusively or between guest's operating system and the host. A special code to be installed is unnecessary.

Otherwise speaking, an injection of a Dynamic Link Library/DLL attack could take advantage of VMware running on the host operating system, granting a license for the App. running on the host to access the memory of the guest's VMware machine, when this took place, the memory buffer will be used as a shared buffer, a shared buffer that provides a mutual environment to initiate communication between the host machine and client. This tool will not have the Virtual Machine to be escaped completely; but enables penetration the boundary between host machine and VMware.

VMcat: This could be defined as a VMchat extension tool to send simple (stdin) and (stdout) files between the mutual environments created in VMchat which could be managed to pipeline a command shell between hosts and guest.

VM Drag-n-Sploit: In this case, a VMware component on the guest called (VMwareService.exe) could be mutated in its form of nature; experts could perceive and shift all data passing through the mutual environment. This leads to manipulate the data being towed from gust to host using function built in VMware station called “drag-n-drop”. The experts used “drag n drop” to prompt command shell from the host to guest.

VMftp: As long as shared folders are enabled, a flaw discovered in iDefense Shared Folder could enables the VMftp tool to take advantage of a user on any guest, regardless of its privilege could read and write to the host.

VII. Escape Classes

There are three main escape classes could be traced in Virtual Machines, these classes are specified depending on the direction pursued by VM’s, as follows:

VM escape to host: breaching the isolation between host and virtualized environment. This happens when code from a VM runs inherently on the host machine apart from any control of the VMM. Since there are weaknesses or flaws in the VMM, attackers aim to attacking virtualized devices, caches of CPUs and Direct Memory Access/DMA to acquire an access to the memory of the host straightly [6].

VM escape to VM: as shown in Fig. 4, a rule of each VM should not change or examine the data of other VM’s is essential. When this rule is breached, it’s called VM escape to VM [6].

VM virtual network escape: as shown in Fig. 5 the breach occurs at the virtual network zone rather than general I/O, namely a VM dodging intended network boundary [6].

As shown in Fig. 6 and unlike other cloud attacks which most have one, two or three impacts on cloud, VM Escape attack could have impacts on confidentiality, integrity, authentication, authorization or even availability of Cloud [7] [8] ; and as long as the hypervisor represents a single point of failure component [9]; and there are types of VM Escapes in which attacker could take control over the whole hypervisor [10], consequently; VM-escape attack is considered to be one of the most catastrophic threats to the Cloud [11]. The seriousness of the attack not only lies in sophistication, it is an ad-hoc and hard to get detected as well [10].

As for aforementioned reasons, Virtual Machine Escape threat has to be solved urgently. It’s good to mention that VM Escape can affect the IaaS layer [12].

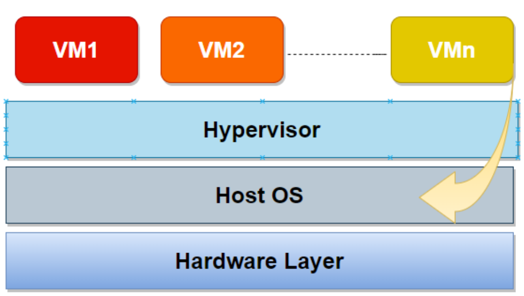

Fig. 4. Demonstration of VM Escape to Host.

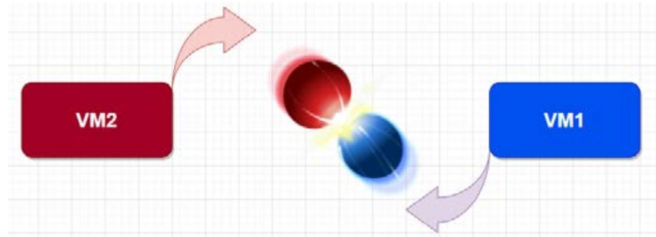

Fig. 5. Demonstration of VM Escape to VM.

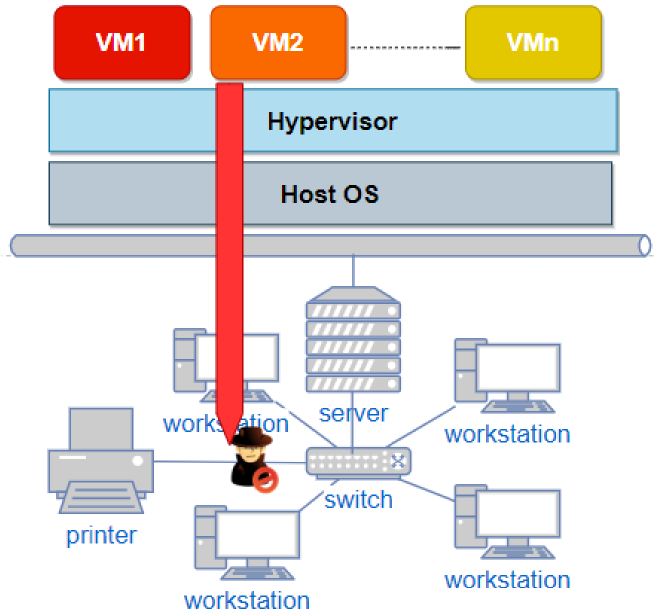

Fig. 6. Demonstration of VM Escape to Network.

Generally, it is of importance; theoretically and practically surveying modality to provide a safe environment to secure this significant sector titled cloud computing and to deter malicious attacks.

VIII. Counter Measures

To some extent, VM Escape attack stands still as an unresolved lofty threat that VM may encounter [7]. Moreover, mitigating or preventing the attack (based on its nature) may require fortification of other cloud components including physical resources rather than VM itself [10].

Nonetheless, there are many approaches security specialists have to keep track to maintain minimum extent to secure VM’s.

In general, a penetration test to be performed to have a general assessment of virtualization environment security. This considered as an essential approach to conduct [9].

Furthermore, the adoption of techniques and methods to -hypervisor-hardening is inevitable [10].

Thwarting Virtual Machine Detection is another approach to secure VM’s from malicious attacks lead to VM Escape; especially there are a growing number of malicious programs conveying code to recognize the presence of virtual environments [13].

Also, hindering of VM Escape attack requires software engineering, Patching and formal verification [7].

Moreover, checking the security & integrity of the Hypervisor; harden and secure the Guest OS; isolate & secure the virtualized network; achieve a real-time Zero-day malicious activities detection; put other controls and security policies in place and restore guest VMs to a clean state automatically [8].

The cloud providers have to provide secure, reliable cloud computing environment. They are bundled to endeavor all possible executions to achieve that goal.

Therefore, Trusted Virtual Domain (TVD) is another approach to secure cloud from VM Escape incidents [6].

Other approaches could be pursued are based on Memory Introspection. A process through which a hardware-based approaches to obtain the physical memory of the host machine in real time, thereby; diagnoses of the security of the host machine and VM could be examined. Furthermore, a new approach to analyze the forensics of VM memory rested on the virtual machine control structure (VMCS) has been triggered. Through scrutinize the host machine memory, the operating VMs could be recognized and the high-level of their semantic data could be rebuilt. Eventually, active malignant in the VMs could be detected in an appropriate time. Moreover, through interpreting the memory quintessence of the VMs and host machine, VM escape could be detected by observing the abnormal attitude pattern of the host machine. So far, a relevant written work to solve the problem of VM escape detection has not been found yet [14].

On the other hand, some experts put forward a restriction access to the Virtual Machine's resources by defining new policies to manage Access Control/Access Control Model. A new system to harden Open Stack called SOS was proposed. SOS comprised of a framework which apply wide layers of security measurements and define trust limits on compute nodes. They have generated a Mandatory Access Control (MAC) to limit the communications between different components. These policies shall be originated automatically.

Nevertheless, this method is not convenient for instant deployment, because running cloud platforms should be modified [11].

The experts proposed several actions to be taken to handle VM Escape using MAC, each method has its advantages and disadvantages, below we shall provide a brief of the tools invented to solve VM Escape based on Mandatory Access Control.

An application of a MAC framework shall be applied to multi-level security (MLS) in Xen based on a Virt-BLP model (Bell-La Padula) [11]. Nevertheless this model secures the communication between VMs; it does not address the problem of interaction between VMs and the Hypervisor.

A design of multilevel security access control V-MLR related to the mandatory access control. This tool provides secure communication environment for VMM and VMs. Also; it provides an update of the acquired information in VMM concurrently when changes on that information occur in VMs. Yet, this tool is related to Xen system of Virtual Machines.

Construction of multilevel security on the basis of BLP model. The level of security in this tool could be changed dynamically, especially when users read critical data. This tool guarantees the aspect of users become unable to leak these critical data they have read. However, results of effectiveness of this model still foggy. The BLP model is originated for the conventional system rather than virtualization system. In spite of both virt-BLP & Prevent Virtual Machine Escape (PVME) [11] are based on the BLP model, they tend to share different approaches though. As example, the PVME model used in full virtualization and principally handles the security problems between Hypervisor and the VMs with regard to the subject of communication. Otherwise, virt-BLP is implemented in Xen VM's, whereas Xen represented as Para virtualization; it primarily addresses the VM's communications security [11].

Also, On the other hand, to solve Escape problems, the interaction of host/guest should be configured properly [15].

However, prevention of the VM escape to host & VM escape to VM classes requires a combination of VMM patching, host security procedures, and methods to disclose the malicious code in the VM.

As long as these two classes enable the attacker to acquire the access to data; It is of logic to be aware that the risks could be mitigated when the specialists seek for encryption of the high value of storage altogether with the assets of communication in order to avoid the disclosure of valued data in case they have been compromised. Specifically, storing encrypted database records on virtual disk shall be secured in case of compromising or reading the file [6].

Furthermore, the Adoption of symmetric/asymmetric algorithms to have encryption of data is a common method to protect the data in Virtualized infrastructure; the most common encryption approach is Service Level Agreements (SLAs) [16].

Other common approaches to secure Virtualized infrastructure could be outlined by firewall service, a virtual firewall (VF) operating within virtual environment could provide constant filtering of packet and monitor the services provided by physical firewall. To achieve this goal, VFs residing at the hypervisor should be applied on the VMM; as long as the VMM is responsible for apprehending malicious Virtual Machine activities including packet insertion. A modification to be applied at the kernel of the physical host hypervisor to enable the installation of modules or hooks granting the VF system an access to the information of VM and an unreserved access to the virtual network in addition to moving packets between VMs at virtualized network interfaces. Yet, these hooks or modules could be used to execute all functions of firewall like dropping, packet inspection, and forwarding. Yet, all of these functions to be performed without palpating the virtual network [16].

As long as the VM Escape attack -In many cases- are based on breaching the isolation between host and virtualized environment or between VMs, therefore keep an eye on the measures preventing this from happening in the isolation property is not a waste of time. Many approaches are available to address this issue [17].

Since the hypervisor represents a probable surface to trigger an attack between two virtual machines, so the removal of VMM to be considered as a radical solution to get rid of this surface through abandoning the hypervisor.

This could be implemented through the adoption of hardware assisted virtualization and placing number of restrictions on virtualization conditions.

However, when VMM removal is implemented, virtualization infrastructure shall lose certain features, as example; VM's became incapable to share resources (buffers, devices, memory) between them as shown in Fig. 7 [17].

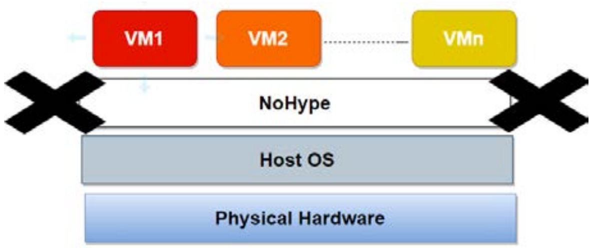

Fig. 7. NoHype Architecture [17].

IX. Conclusion

In general, this paper introduced most of the main VM Escape attacks details. Beginning from the VM Escape definition; ending with the methods undertaken to put down or soften it. Furthermore we have stopped at several tools and techniques could trigger VM Escape attack. For all that regulations listed/available to confront VM Escape attack alone or along with other possible attacks, VM Escape is such a stubborn threat cloud might come across.

As aforementioned above, there are many regulations to seek countering VM Escape attacks; and experts are in a big race to curb that vicious attack. Nonetheless; the attackers are matching their steps to level up their tools and techniques to come up with new VM Escape patterns & styles to beat these assumed preventing regulations.

Throughout the demonstration of VM Escape attack which is - as with the rest of the other VM attacks - based on a real vulnerability in VM's; in addition to the serious impact could be occurred by this type of attacks which - in some cases - threatening availability of the Cloud; taking into account other bunch of attacks that target VM's; therefore, VM shall be considered as of the most fragile component of cloud.

Definitely, experts seek to have a free of defects cloud. Ultimately, unstoppable attack requires - even though considering cauterizing the cloud-which represents the eventual medicine. Accordingly, the consideration of shifting cloud from VM's to Containers is believed to be as an enhancement for the whole cloud performance.

Recently, migration from using VM's towards an alternative option characterized by Containers is increasing [18].

Yet, while the cloud is pulsing somewhere, the danger shall be lurking and the battlefield shall persist.

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The Language of Persuasion in Courtroom Discourse: A Computer-Aided Text Analysis

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***Abstract*—This paper uses a Computer-Aided Text Analysis (CATA) and a Critical Discourse Analysis (CDA) to investigate the language of persuasion in courtroom discourse. More specifically, the paper tries to explore the extent to which a computer-aided text analysis contributes to decoding the various persuasive strategies employed to control, defend or accuse within the framework of courtroom discourse. Two research questions are tackled in this paper: first, what are the strategies of persuasion employed in the selected data? Second, how can a computer-aided text analysis reveal these persuasive tools that influence the attitudes of recipients? By means of the adopted computer-assisted textual analysis, four CDA strategies are discussed in this study: *questioning, repetition, emotive language, and justification*. The paper reveals that language in courtroom discourse can be used to persuade or biased to manipulate. In both cases, a triadic relationship between language, law, and computer is emphasized.**

Keywords—Computer-aided text analysis; legal discourse; persuasion; critical discourse analysis; power; control

I. Introduction

Within the framework of legal settings, language is a powerful tool for persuasion. Linguistic expressions are widely employed in court to defend or to accuse. Language is perceived as a tool that reflects social control and power [1]. This sociolinguistic characteristic is not only noticeable in social settings, but also in legal settings [2]. In courtrooms, language is used and/or abused to facilitate control and to exercise power among discourse participants, be they lawyers, judges, witnesses, or otherwise. This is because a trial is a linguistic activity in which a linguistic interaction is meant by language users to advocate their position and to challenge their opponents. Language in this sense is perceived as a tool of control. Thus, one can say that there is a reciprocal relationship between language and legal discourse; reciprocal in the sense that the latter is interpreted according to the linguistic interpretation of the former in discourse. From this context, the relationship between language and law can be said to be worthy of linguistic research. This relationship is analytically accentuated by the application of a computer-aided text analysis in order to explore the ways through which language is used within the framework of courtroom discourse. This article, therefore, attempts to present a corpus linguistic analysis of Moussaoui's trial in 2006, by using critical discourse analysis approach through discussing certain persuasive devices used in the opening statements of the defense attorney and the U.S. government attorney in such a case. Here, the focus is on the persuasive power of language; that is, how it is persuasively used in such a type of discourse (i.e. legal discourse) to influence the attitudinal behavior of recipients.

A. *Objectives of the Study*

This study tries to achieve the following objectives:

1) To shed light on the analytical relevance of applying a computer-aided text analysis to the investigation of legal language.

2) To explore the different persuasion tactics used in courtroom discourse.

3) To demonstrate the extent to which persuasive tools facilitate control and influence attitudes among legal discourse participants.

4) To highlight the triadic relationship between language, law, and computer in terms of discourse interpretation, and within written legal discourse.

5) To reflect on the way courtroom discourse serves as a tool of institutional empowerment and control.

B. *Research Questions*

Two main research questions this study attempts to answer:

1) What are the strategies of persuasion employed in the selected data?

2) How can a computer-aided text analysis reveal these persuasive tools?

C. *Significance of the Study*

The significance of this paper lies in its attempt to offer a corpus linguistic analysis that functions to reveal hidden strategies of persuasion beyond the mere legal and linguistic expressions in courtroom interaction. This is conducted by virtue of a computer-aided text analysis of the corpus under investigation. As such, the paper tries to shed light on the possibility and the relevance of applying computer software programs to the linguistic and discursive analysis of texts. Crucially, using computer software to reveal hidden persuasive strategies, the core concern of this paper, aims to offer better understanding of the way language is used and/or

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abused to achieve the goals of its users within different legal settings. This linguistic analysis attempts to offer insights into the understanding of the different uses of language to produce persuasion in legal discourse, which also aims to emphasize the relationship between language, law, and computer. The study, therefore, provides some sort of computational linguistic enlightenment to the ways through which language is used or abused in legal settings.

The remainder of this paper is structured as follows. Section 2 presents some theoretical preliminaries and reviews the literature relevant to the topic under investigation. Section 3 provides the methodology of the study. Section 4 is the analysis of the selected data. Section 5 offers the conclusion of the article and recommends further studies for future research.

II. Literature Review

A. Computer-Aided Text Analysis

A Computer-Aided Text Analysis (henceforth, CATA) provides the possibility of performing content analysis on a large amount of data. This computer-based software helps researchers and text analysts arrive at specific indicators that play a part in the interpretation of texts within the framework of corpus linguistics [3]. CATA can be used to identify the linguistic significance of words, either individual words or words in company; that is, words in their contextual occurrence in text [4, 5].

Content analysis is one of the options achieved by CATA. According to Weber [6], content analysis is a systematic, replicable approach for compressing words of a text into content categories that are based on explicit rules of coding. In so doing, this type of analysis can help in classifying data into categories by focusing on the semantic of words that can be put together to form a larger class of a particular content (theme). As such, CATA can be applied to different types of texts, including courtroom discourse, particularly opening statements delivered in these settings, the main concern of this study.

Frequency Distribution Analysis (FDA) is another variable addressed by CATA. This option is based on the assumption that specific words are selected from the text under investigation to undergo a frequency analysis [7]. This type of analysis functions to arrive at the number of occurrences a selected word has in text, which, in turn, helps text analysts derive their linguistic results, either discursively or otherwise.

A KeyWord in Context (KWIC) is a further analytical option that can be targeted by CATA [8]. This analytical dimension reveals the contextual environment in which a specific word or phrase is used in text. This also sheds light on the linguistic significance of certain words. Significantly, both frequency distribution analysis and keyword in context can be realized by Concordance, which is also available within CATA framework. According to [9] and [10], concordance is a computer software program through which large amount of data can be collected, accessed, classified, and analyzed to arrive at particular results contributive to corpus linguistics of texts. Thus, the use of concordance offers some sort of analytical extension that can retrieve all occurrences, as well as all keyword contexts occurred in a corpus [11, 12].

B. Legal Discourse Studies

The language of legal discourse has attracted many scholars, including legal experts, philosophers, linguists and other practitioners of this genre. These scholars from different disciplines provide much literature addressing legal discourse from different perspectives: by discussing the relationship between language and law via shedding light on the different linguistic aspects operating in legal texts [13, 14]; by decoding the lexico-grammatical features of the legal texts [15]; by exploring power relations between participants in courtrooms contexts [16, 17]; by focusing on the influence of language in the interpretation of legal discourse [18]; by offering new insights into the relevant social role of language to legal discourse within legal communities, with the intention to discuss concepts related to identities and culture [19, 20, 21, 22, 23]. The main focus of these studies revolves around the role of language in producing, reproducing, or legitimizing power relations within the framework of legal discourse. They describe the way through which law, with its actors inside the arena of legal discourse practices, conceives the relationship between discourse, power and ideology.

Further insights have also been offered to the manner through which language is skillfully employed within legal communities to negotiate issues of justice [24]; and the way aspects of language are practiced and negotiated by legal discourse practitioners [25]. Other studies have tackled other topics in courtroom discourse from different perspectives. Among these studies is [26] whose contribution in legal discourse focuses on the analysis of legal language in written contracts. They shed light on the linguistic devices used in writing contracts such as the use of modality for obligation. Other contributions concentrate on aspects of power, control, gender, discrimination, and dominance in the courtroom [27, 28]. From this context, it can be noticed that legal discourse studies do not isolate themselves from the linguistic context of the language used in legal texts. Thus, there is often a connection between language and legal texts; a connection in the sense that various legal texts, such as contracts, legislation and regulations, related to national and international jurisdictions, have been addressed not only from a legal angle, but also from a purely linguistic perspective. This shows the relevance of the different linguistic levels of analysis, such as the semantic, the pragmatic and the syntactic in the interpretation of legal texts.

C. Law and Language: A Reciprocal Relationship

Language is closely related to law, and the language of law, either spoken or written, constitutes various linguistic concepts that are worthy of linguistic research. This relationship has been the focus of many studies [29, 30]. In courtrooms, many laws are presented to defend or accuse. These laws are presented in an oral interaction that operates in a contextual environment of legal discourse. The interpretation of such laws depends to a high degree to the way language expressing these laws encodes ideology. The ability of discourse participants to perceive what beyond the mere linguistic expressions of laws, the way they are delivered in courtrooms, and the pragma-semantic meanings these linguistic expression convey makes discourse participants linguistically acquainted with enough information relevant to provide a proper interpretation for what is being communicated.

D. *Courtroom Discourse*

Courtroom discourse is a type of discourse delivered within the context of the courts of law. This type of discourse is often presented in a spoken form and is completely different from the type of discourse delivered in everyday interaction [31]. It depends on oral interaction between discourse participants to defend or challenge a specific argument in a particular way. This process of defense is largely based on the use of language, which in turn manifests itself either persuasively or manipulatively. The concepts of persuasiveness in courtroom discourse are determined by the extent to which speakers use language, as well as the readiness of the addressees to accept what is being communicated quite willingly.

Crucially, the function of language in courtroom discourse is not primarily linguistic; however, it is to defend the restoration of social order when it breaks down. This, of course, is delivered within a linguistic framework that facilitates the task of speakers and allows the realization of their desires so easily [32]. Obviously, courtroom discourse is characterized by the imbalances in power relations among discourse participants. Thus, there are two types of power here: a supreme power practiced by judges and another form of power derived from a background knowledge pertaining to lawyers' schemata concerning law. These types of power are exercised from one party over another in order to achieve specific purposes that serve the speaker. Importantly, in most cases, the notion that one party (speaker) is superior over another is ultimately based on the dexterous use of language [33].

E. *Critical Discourse Analysis*

Critical Discourse Analysis (CDA) perceives language as a carrier of ideological purposes. It addresses issues of power and ideology and shows the way language reflects power, control and discrimination among discourse participants [34]. This theory (i.e. critical discourse analysis) attempts to uncover the hidden relations of power in discourse in general and in courtrooms in particular. CDA is described as critical since it criticizes the way language can be biased towards specific ideological assumptions of its users [35]. It exposes the hidden ideologies and offers useful insights towards the understanding of the use of language in different types of discourse. van Dijk [36] considers CDA as a type of analytical research which is concerned with the ways through which power, dominance and inequality are produced, reproduced and exercised in text and talk within the different social and political contexts. Fairclough and Wodak [37] also postulate that CDA considers discourse as a form of social practice and takes consideration of the context of language use to be crucial to discourse. As such CDA focuses on the way language is used to produce control and exercise power in discourse, either spoken or written.

One intrinsic characteristic of CDA is its analytical ability to discover meaning beyond the superficial linguistic expressions of discourse. In this regard, Fairclough [38] argues that CDA has the capacity to explore obscure discursive relationships of causality and determination between two main elements in discourse: the discursive practices and the wider social and cultural structures, relations and processes. As such, CDA's theoretical and analytical agenda allows critical analysts to investigate the way such discursive practices and texts are loaded with different relations of ideology and power. CDA aims to describe, explain and interpret the relationship between discursive practices, social practices, and social structures [1]. In courtroom discourse, such relationships are clearly represented by discourse participants, be they judges, lawyers, witnesses, or otherwise [39]. CDA, therefore, attempts to uncover hidden ideologies in discourse practices and beyond. That is, it scrutinizes to analytically connect between the micro structures of discourse, which focuses on the linguistic devices used in texts and talks, and the macro structures, manifested in the analysis of the context of situation. This analytical connection operates effectively in legal settings, wherein a connection between the linguistic expressions and their contextual environment is highly indicative.

F. *Discourse and Persuasion*

Persuasion has been tackled by many linguists and sociolinguists [40, 41, 42]. Whateley [43] perceives persuasion as a science which constitutes the ability to use proper arguments to prove what one wants to communicate and achieve. Bryant [44] clarifies that persuasion is a process of subjugating specific ideas to different people and different people to specific ideas. For Lakoff [40], persuasion is an intentionally-based process that aims to reshape the behaviors of others by means of specific communicative means. Jowett and O' Donnell [41] consider persuasion as an interactive process of communication in which a speaker attempts intentionally to influence the beliefs and attitudes of receivers.

To Pardo [45], persuasion appears to be a linguistically-based phenomenon used by one person to convince another of something. The different definitions of persuasion emphasize that it is a communicative process whereby speakers try to adjust, change, and influence others' attitudes to suit their own advantages. This perceives the study of persuasion as relevant to legal discourse and courtroom interaction. Persuasion is necessarily linked to power and therefore it always entails some degree of it. For [45], the point at which persuasion becomes manipulation or coercion depends on the extent to which power is exercised in discourse. In courtroom settings, this power can be exercised both persuasively and manipulatively in order to influence the attitude of recipients so as for them to adopt the speakers' point of view. Lawyers, thus, are supposed to use language in the opening statements in order to persuade the court of their client's position.

III. Methodology

This part is dedicated to presenting the process of data collection, data description, the rationale of the study and the framework of data analysis.

A. Data

The data used in the analysis of this paper consists of the two opening statements of Zacarias Moussaoui trial, a French citizen of Moroccan descent who was convicted of being involved in the terrorist attacks on the World Trade Center on September 11, 2001. Moussaoui's trial was located in the United States District Court, the Eastern District of Virginia, and dated March 6, 2006. The first opening statement is of U.S. Attorney Robert Spencer in the Moussaoui trial, which consists of 26 pages and counts nearly 6411 words. The second is of defense attorney Edward MacMahon, which consists of 31 pages and counts nearly 7571 words. The collected data is available at https://famous-trials.com/ moussaoui/1830-moussaouiexcerpts. Table I offers a description of the selected data.

TABLE I. Data Description

Description	**Opening Statement of US Government**	**Opening Statement of Defense**
Attorney (speaker)	Robert Spencer	Edward MacMahon
Number of Pages	26	31
Number of Words	6411	7571
Number of lines	642	754

The rationale constituting the selection of this trial in particular is due to three reasons. First, this case (i.e., Moussaoui trial) represents one part of the most effective event that reshapes world opinions in general and the American one in particular in terms of the image of Muslims and Islam. Second, the terrorist attacks on the World Trade Center directed the world accusation fingers to Al Qaeda and Osama bin Laden, the two symbols of terrorism against the West in the then time. Third, the selected trial reflects a type of legal discourse in a courtroom setting that shows the manner through which persuasion tactics are linguistically employed to achieve specific purposes of language users.

B. Opening Statements

Unlike the other elements in courtroom legal activities, opening statements are allowed to be delivered without any intervening activities from the court. That is, attorneys have the chance to expose the guidelines of their defense without interruption. This uninterrupted freedom of speech delivery facilitates their task to deliver their arguments persuasively. Johnson [46] emphasizes this characteristic by arguing that they represent the first opportunity to communicate persuasively and argumentatively with the jury without interruption. Through opening statements, attorneys can present their evidences concerning a case in hand. They are attempts to persuade the judge to issue a favorable verdict. According to Bradshaw [47], an opening statement should have a beginning, middle and an end. In other words, it should have an introduction, a body and a conclusion, through which the story and the theory of the case, its context of situation, evidences and counter evidences are supposed to deliver persuasively to win a positive legal stance [48, 49]. Thus, the effectiveness of opening statements is measured by the lawyer's ability to persuade the judge to adopt a situation that benefits the defendant.

C. Framework of Data Analysis

Certain persuasive strategies used in the selected trial by the attorneys will be covered in the part of the analysis. These include the following: *questioning*, *repetition*, *emotive language*, and *justification*.

1) Questioning: within courtrooms, the act of questioning is one of the best ways of extracting information needed, either from the convicted person or the witnesses. This type of extracted information functions to persuade the judge of the case as a whole and thus enables him to give the final verdict. Questions in courtroom discourse may be in a form of yes/no questions, wh-questions, or rhetorical questions [50].

2) Repetition: This strategy depends on repeating certain words or ideas to achieve specific purposes on the part of the addressees. Brembeck and Howell [51] argue that repetition functions to attract attention to an idea or argument for some ideological purposes. They maintain that repetition is very important in communicating and emphasizing ideas among participants which, in turn, is essential in the process of persuasion.

3) Justification: Legal representatives always manipulate certain tactics of justifications in order to convince their participants of their arguments. van Dijk [52] states that justification is required in interaction between participants to legitimize their arguments. This strategy is employed in the selected data by the legal representatives to manipulate their recipients into submission to their arguments.

4) Emotive language: Using emotive language is another tool legal representatives use to affect their participants (the Jury, the Judge). Crucially, addressing the emotions of the recipients by employing words that may possibly develop and stimulate their potential is indicative in the production of a legal persuasive discourse [38].

IV. Analysis and Results

A. Questioning

In the two opening statements selected for study in this paper, questioning represents a fundamental element in Moussaoui's trial. In their opening statements, both defense attorney Edward MacMahon and the U.S. attorney Robert Spencer make use of this strategy. Regardless the fact that the defense attorney uses questioning (13 occurrences) more that his counterpart (4 occurrences), but all employed questions play a pivotal role in the process of persuasion within the court. Both attorneys utilize questions in their opening statements metalinguistically as is shown in the following selected extracts from the defense attorney Edward MacMahon:

1) And *who are we?* We're a nation that's governed by laws and the Constitution. We try to provide equal justice to everyone. (Moussaoui Trial ‘henceforth MT., [53], my emphasis).

2) So whatever role the government may say that Moussaoui played in the attacks, it was obviously so inconsequential that the attacks went forward in his absence and entirely without his participation. *How?* Because the evidence will show that Moussaoui wasn't part of the plot and was ignorant of its details. (MT., [53], my emphasis).

3) Khallad, our government says in e-mails that you will see in this case, was a major league killer. Did alarm bells go off? Did the government launch a massive manhunt for Khallad's lieutenants in the United *States?* You know the answer. (MT., [53], my emphasis).

4) Has the government ever heard of Airman Flight School before, ladies and gentlemen? Before 9/11, you will learn that Airman Flight School had hosted other al Qaeda members as flight students. Our government knew all of this before September 11th. (MT., [53], my emphasis).

The above extracts 1, 2, 3 and 4 display a dexterous use of metalinguistic questions; two of them have been initiated by the interrogative operators who and how, whereas the other two questions are in the yes/no form communicated by the auxiliaries did and has. Significantly, in all their semantic interrogative forms, the four questions above have a metalinguistic pragmatic function beyond their surface semantic directivity. That is, the four questions do not seek an answer, or prospect any response from recipients. However, they are employed to confirm a piece of information and to stimulate a cognitive work towards a specific argument. In 1 and 2 above, the metalinguistic questions are followed by their answer in an attempt to convey the meaning that the United States of America is a country of justice, in a reference that stimulate the fixed rules of the country so as to sympathize with Moussaoui (in 1), and that the defense attorney have evidences supporting Moussaoui’s situation in the trial. Likewise, the answer of the metalinguistic question in 3 you know the answer aims to activate the jury as well as the audiences’ thinking so as to ask themselves the same question and to seek the answer. Here, the answer of 3 carries the inferable meaning that facts and evidences of Moussaoui’s innocence is apparent to everyone. This inferably pragmatic interpretation is also emphasized by the answer of 4 our government knew all of this before September 11th. Crucially, launching these questions, together with their immediately subsequent answer raises the possibility of persuasiveness on the part of the addressees. Consider Table II.

TABLE II. FREQUENCY ANALYSIS OF QUESTIONS USED TO PERSUADE IN DEFENSE ATTORNEY OPENING STATEMENT

Questioning				
Opening Statement of Defense Attorney Edward MacMahon				
Type of question	W-h questions	Yes/no questions	Rhetorical questions	Total
Frequency	6	5	2	13
Indicative Occurrences	6	4	2	12

In a similar vein, the U.S. attorney Robert Spencer employs metalinguistic questions in his opening statement:

Before 9/11, anyone selected by the CAAPS system couldn't check their bag on to a plane until they themselves boarded the plane. Why? Because the FAA before 9/11 was concerned about people smuggling explosives in checked luggage onto planes. (MT., [53], my emphasis).

Spencer does not expect an answer. He asks his question and follows it with the answer. Here, he tries to highlight Moussaoui’s accusation and to dissociate the U.S government from responsibility. Spencer’s metalinguistic question then targets one meaning: the United States of America does not bear any responsibilities for the September 11th attacks, as it has taken all safety and security measures that were followed then. Courtroom questioning, in light of the analysis in this paper, are not intended to extract information, as is the case for interrogatives in any discourse settings. However, they are employed to communicate information, to stimulate a cognitive work and to confirm an argument. Consider Table III.

TABLE III. FREQUENCY ANALYSIS OF QUESTIONS USED TO PERSUADE IN U.S. ATTORNEY OPENING STATEMENT

Questioning				
Opening Statement of U. S. Attorney Robert Spencer				
Type of question	W-h questions	Yes/no questions	Rhetorical questions	Total
Frequency	2	1	1	4
Indicative Occurrences	1	0	0	1

B. Repetition

Repetition is a critical discourse strategy used by speakers to affect a persuasive change in the attitudes of recipients. According to [51], repetition serves to clarify and to hold attention to an idea. This effect becomes more effective when certain repetitive expressions are recurrently used in the same speech/text. Repetition may appear in two forms: "either by using the same words or by stating the same idea in different words" [51]. In the selected data, repetition is employed in the two opening statements. See the following extract:

1) You can't judge him to get revenge for 9/11. You can't make him some substitute for Osama bin Laden. And you can't make him a scapegoat for what government officials did not do. (MT., [53], my emphasis)

The above words are said by the defense attorney towards the end of his opening statement. The repetitive expression you can’t + infinitive emphasizes the function of language in communicating information. These expressions, for Letteri [54], are called “anaphoric expressions” and means the repetition of a word or phrase at the beginning of consecutive clauses or sentences. When repetition is employed, it aims at emphasizing the specific ideas or words that are repeated in discourse. As such, by using repetition, attorneys tend to effectively persuade their audiences. In fact, language has a variety of functions, but when it comes to confirmation of information, its significance is measured by what is repeated and the reason why this repetition takes place. As indicated in the above extract, repetition carries a pragmatic function, as it aims to confirm the specific meaning of innocence on the part of Moussaoui. This correlates with Pridham's argument [55] that speakers often repeat their arguments more than one time in order to ensure cooperation and full understanding. Pridham clarifies that repetition enables the speakers to check and then to confirm what has been said. Repetition, here, is employed to state the position of the defense attorney so as to help ensure comprehension of what he has been said and meant. Thus, repetition is very important in communicating and emphasizing ideas among participants which, in turn, is essential in the process of persuasion.

Another example of repetition can be found in the following extract from the opening statement of the U.S. Attorney:

2) On that day, September 11th, 2001, Moussaoui was a member of al Qaeda. On that day Moussaoui was part of the plot to hijack planes and crash them into U.S. buildings to kill as many U.S. Americans as possible. Moussaoui trained with al Qaeda as part of the plot. Moussaoui traveled to the U.S. as part of the plot. Moussaoui took flight training as part of the plot. Moussaoui purchased short-bladed knives, all part of the plot, all financed by al Qaeda as part of the plot. He was in the thick of it. (MT., [53], my emphasis).

As indicated in the above extract, repetition is utilized to emphasize an idea and to support an argument. The repetition of the prepositional phrase on that day functions to bring back the picture of what happened to the court, as well as to the addressees' minds. Also indicative is the repetition of the proper noun Moussaoui, which tends to cast emphasis on the identity of the person who is responsible for the attack. The use of the past tense that follows also aims to communicate actions verification and completeness. Repetition, here, is an important device because it allows the speaker to place emphasis on things he chooses as significant. It also tells the audience that the words being used are central enough to be repeated, and lets them know when to pay special attention to the language.

On the word level, certain words are used repeatedly in the two opening statements to carry specific meanings. For example, the lexis terrorist, kill, justice, attack, destruction, etc. with their different derivatives, are repeated in the two opening statements, as is clarified in Table IV.

As indicated in Table IV, specific words are used in the two opening statements to communicate particular meanings that aim to affect a persuasive discourse on the part of audiences. Words, such as kill, terrorist, attack, killers display high frequencies in the two statements; however, each attorney uses them for a goal contradictory to the other party. This contradictory objective is manifested in the discrepancy in the frequency of the same words used in each statement. That is, the US representative tries to persuade the court that Moussaoui is completely guilty, whereas the defense attorney attempts to prove the opposite: Moussaoui's innocence. Also indicative is the use of the proper name Moussaoui in the two statements, as well as the phrase September 11th. Again each usage has its target that serves his intention.

TABLE IV. FREQUENCY OF REPETITIVE INDICATIVE WORDS

Repetition		
Word	Frequency	
	Opening Statement of U. S. Attorney Robert Spencer	Opening Statement of Defense Attorney Edward MacMahon
Moussaoui	104	97
Kill	25	4
Terrorist	15	5
Attack	5	39
Terrorism	2	4
Killers	4	3
Terror	2	10
Horror	1	1
September 11th	22	31
Destruction	2	0
Destroy	1	0
Justice	0	3
Slaughtered	1	0

Further, other words in company are repeated in the two opening statements to carry ideological significance to the thematic and persuasive message intended beyond the two statements. Consider Table V.

TABLE V. FREQUENCY OF INDICATIVE WORDS IN COMPANY

Repetition		
Word in Company	Frequency	
	Opening Statement of U. S. Attorney Robert Spencer	Opening Statement of Defense Attorney Edward MacMahon
Your honor	2	2
Muslim fundamentalists	1	16
Innocent Americans	2	0
Civilian personnel	2	0
Civilian people	1	0
Cold blood	1	0
Cold-blooded killers	1	0
Al Qaeda member	19	14
Al Qaeda associate	12	9

Table V shows some words in company with others, that is, in their contextual environment. This functions to reveal the ideological persuasive significance of these words. Thus, the use of the collocation your honor by the two attorneys is noticed, which indicates a commitment to particular terms of address in courtrooms. Also, the word Muslim is accompanied by fundamentalists to convey further terrorist meanings. Furthermore, the combination of Innocent, Civilian, and Al Qaeda to American, personnel, people, member, and associate, respectively, is highly indicative in the process of persuasion.

C. Justification

Attorneys always manipulate certain tactics of justification in order to distance their legal clients from being blamed for any mischief. This strategy is dexterously employed in the selected data, as is shown in the following extracts:

1) Mr. Moussaoui introduced himself to you by proclaiming that he was al Qaeda and that we were all Americans. And on this point, and it may be the only one, I wholeheartedly agree with him. We all know that al Qaeda is a fanatic Islamic-based terror group, and we all know that their favorite weapon is suicide terrorism. Now, what we call suicide, they call martyrdom. And martyrdom is something special to an al Qaeda member. It is just what they yearn for. They live so that they can die. (MT., [53], my emphasis).

The above quote represents one of the most effective justifications used in the two opening statements under investigation. The defendant's lawyer has tried to blame a systematic ideology of a terrorist group (i.e., Al Qaeda). He is trying to prove that Moussaoui's problem lies in his involvement in an ideology-based extremist movement, which portrays him as a martyr who attains the highest degrees in heaven as a reward of any terrorist attack what we call suicide, they call martyrdom. Here lies the difference in ideology between the Western culture represented in the United States of America, the subject of the terrorist attack, and the Islamic countries from the point of view of the lawyer. This justification aims to transform the issue from a personal issue to an ideological one. The inferable meaning here is that Moussaoui is a victim of a systematic brainwashing process by Al Qaeda.

TABLE VI. FREQUENCY OF INDICATIVE WORDS USED TO JUSTIFY

Justification		
Word	Frequency	
	Opening Statement of U. S. Attorney Robert Spencer	Opening Statement of Defense Attorney Edward MacMahon
Martyrdom	0	5
Martyr	0	1
Al Qaeda	31	23
Constitution	0	3
Victims	2	2
Conspiracy	1	0
Conspirators	5	0

Table VI demonstrates a number of words and their frequencies in the two opening statements. These words are employed to justify the situation of each party, either on the part of the US Attorney or the defense representative.

D. Using Emotive Language

Addressing the emotions of the recipients by employing words that may possibly develop and stimulate their potential is another strategy that can produce a persuasive discourse [56]. In light of this paper, certain linguistic expressions are used by the U.S. attorney to address the emotions of his audience. See the following extracts that are delivered at the very beginning of his opening statement:

1) September 11th, 2001 dawned clear, crisp and blue in the northeast United States. In lower Manhattan in the Twin Towers of the World Trade Center, workers sat down at their desks tending to e-mail and phone messages from the previous days. In the Pentagon in Arlington, Virginia, military and civilian personnel sat in briefings, were focused on their paperwork. In those clear blue skies over New York, over Virginia, and over Pennsylvania, in two American Airlines jets and in two United Airlines jets, weary travelers sipped their coffee and read their morning papers as flight attendants made their first rounds. (MT., [53], my emphasis).

2) But a day that started so normally and with such promise, soon became a day of abject horror. By morning's end, 2,972 people were slaughtered in cold blood. And that clear, blue sky became clouded with dark smoke that rose from the Trade Towers of New York, from the Pentagon in Virginia, and from a field in rural Pennsylvania. And within a few hours out of that clear, blue sky came terror, pain, misery, and death, and those 2,972 never again saw their loved ones, never again gave their kids a goodnight kiss. That day, September 11th, 2001, became a defining moment, not just for 2,972 families, but for a generation. (MT., [53], my emphasis).

The above extracts represent a clear example of employing emotive language to stimulate the sympathy of recipients. The two extracts communicate two contradictory pictures of the situation immediately before and after 11 September attacks. The U.S. Attorney representative tries to stimulate his audiences emotionally in order to influence their attitude and make them respond in a way that serves his purposes. In fact, delineating the situation before and after the terrorist attacks brings to the minds of listeners the atrocities committed against humanity in such a day. Discursively, addressing the emotions of discourse recipients always targets a shift in their attitudes towards the issue addressed [57]. Textually, the two extracts are structured around a semantically oppositional discourse, wherein some expressions, such as *dawned clear, crisp and blue, civilian personnel, clear blue skies,* and *weary travelers* in extract (1) are semantically counterparted with *a day of abject horror, people were slaughtered in cold blood, clouded with dark smoke, out of that clear, blue sky came terror, pain, misery, and death*. These expressions serve to motivate the emotions of recipients, which in turn aims to make them adopt only one attitude that serves the goals and allegations of the U.S. representative in the case.

TABLE VII. FREQUENCY OF INDICATIVE EXPRESSIONS USED TO AFFECT EMOTIONS

Emotive Language			
Opening Statement of U. S. Attorney Robert Spencer		Opening Statement of Defense Attorney Edward MacMahon	
Expression	Freq.	Expression	Freq.
September 11th, 2001 dawned clear	1	This case poses the ultimate test to our legal system	1
Crisp and blue in the northeast United States	2	Our justice system can only be judged by how it treats the poorest	1
Civilian personnel sat in briefings, were focused on their paperwork.	2	The most despicable person who is charged with the most heinous of crimes	1
In those clear blue skies over New York	1	The prison jumpsuit that he will wear for the rest of his life	1
Weary travelers sipped their coffee and read their morning papers	1	We're a nation that's governed by laws and the Constitution	1
Soon became a day of abject horror	1	We try to provide equal justice to everyone	1
People were slaughtered people were slaughtered in cold blood	2	Our Constitution guarantees to all defendants the right to a jury trial	1
Sky was clouded with dark smoke	1	A check against the abuse of government power	1
Out of that clear, blue sky came terror, pain, misery, and death.	1	But he has not admitted any involvement in the September 11th attacks	1

Table VII clarifies a number of expressions used to affect the emotions of both the audience and the court towards the addressed case. Each part tries to address the emotions of the recipients by employing expressions that may possibly develop and stimulate their potential towards action, which in turn influences a persuasive legal discourse.

V. CONCLUSION

This paper used a computer-aided text analysis manifested in a frequency distribution analysis and the keyword in context analysis, together with critical discourse analysis to present a linguistic investigation of the language of persuasion in courtroom discourse. This is conducted by shedding a computational linguistic light on certain strategies of persuasion used in the selected data. These strategies include questioning, repetition, justification and addressing emotive language. The four CDA strategies show the extent to which language is used to produce a persuasive discourse, and emphasize the assumption that CDA is a deconstructive approach to the analysis of power and ideology in discourse [58]. The paper also demonstrated that courtroom discourse is a type of institutional discourse characterized by inequality in power relations among discourse participants. This type of discourse is goal oriented; that is, it always targets specific purposes beyond the discursive practices delivered in court settings. The four devices are intentionally utilized by discourse participants to guarantee the realization of their intended purposes and the acceptance of their arguments in a particular way.

The analysis further showed the relevance of applying a computer-assisted analysis and a critical discourse analysis to the study of courtroom discourse. This in turn emphasizes the relationship between critical discourse analysis, as a multidisciplinary approach, the language of law, and computer applications in corpus linguistics. Finally, for future research, this paper recommends further linguistic studies on other courtroom popular cases (e.g., former Iraqi president Saddam Hussien’s trial). This could reveal similar or different findings than what this study provides in terms of the CDA strategies used among discourse participants and the way these linguistic devices operate in legal settings and revealed by computational tools.

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Differential Evolution-based Approach for Tone-Mapping of High Dynamic Range Images

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***Abstract*—Recently, high dynamic range (HDR) imaging has received significant attention from research community as well as the industrial companies due to valuable applications of HDR images in better visualization and analysis. However, HDR images need to be converted to low dynamic range (LDR) images for viewing on standard LDR display screens. Several tone-mapping operators have been proposed for the conversion, however, so far, no significant works have been reported employing artificial intelligence to achieve better enhancement of the output images. In this paper, we present an optimization-based approach, to enhance the quality of the tone-mapped LDR images using metaheuristics. More specifically, the optimization process is based on the differential evolution (DE) algorithm which takes tone-mapping function of an existing histogram-based method as initial guess and refines the histogram bins iteratively leading to progressive enhancement of the quality of LDR image. The final results produced by the proposed optimized histogram-based approach (OHbA) showed better performance compared to the existing state-of-the-art tone-mapping algorithms.**

***Keywords*—HDR image; LDR image; metaheuritics; differential evolution; tone-mapping; histogram**

I. Introduction

The human visual system (HVS) can adapt to the high dynamic range (HDR) of natural and synthetic scenes for viewing details of the dark and bright regions. However, the capturing of devices, such as commonly used cameras, suffer from sensor limitations and loss of precision in the quantization process for storing on digital media [1-2]. This is to say that the images captured with standard cameras and displayed on standard screens have lower quality than the actual scene viewed by the human eye. This gap in quality inspired research works on development of software and hardware technologies for capturing and displaying high quality images using HDR image and video technologies. HDR images have valuable advantages in many fields of life, such as realistic visualization experience, better scene analysis, gaming, and enhancement of medical images for correct and accurate diagnoses among others [3-4].

In image processing, the dynamic range refers to the ratio between the intensities of the brightest and darkest pixels of the scene. Fig. 1 shows typical brightness levels of different objects that we come across in our daily life. When objects, of very different brightness, are present together in a scene, the scene is referred as an HDR scene. In a real-life example, a sunny natural scene with shadows and light sources and/or light reflections present in it is an HDR scene. Recently, new designs of cameras have emerged which can capture much larger dynamic range of the scene than the standard cameras [5-6]. However a more commonly used technique to capture HDR scenes is to take a series of shots by varying the exposure time setting of the camera, and merging them to a single HDR image using a technique generally referred as exposure fusion [7-10]. The merging process requires carefully removing the effect of moving objects and many techniques have been proposed for this purpose [11-12]. In the current state of imaging technology, high dynamic range of natural scenes can be captured quite reliably, and the recent focus is mainly on improving the speed of operation and reconstruction of HDR from a single LDR image using deep learning approaches [13].

Replicating an HDR scene on a standard screen is a challenging problem due to several factors, most importantly due to limitation of the hardware. New HDR displays have hit the consumer market, but their dynamic range is still much lower than the dynamic range of HDR images. An HDR image shown on an LDR display without any processing might look like one of the shots shown in Fig. 2 depending on the display settings. For a better viewing experience, a tone mapping operator (TMO) is required. The term refers to the algorithms used to match the dynamic range of the content with that of the screen. In general, the TMOs enhance the brightness of dark pixels and compress that for the bright pixels. Many TMOs use some model of HVS characteristics to produce results of better visual quality.

Fig. 1. Brightness Levels of different Objects.

Fig. 2. An HDR Sunny Scene Captured with different Exposure Settings of a Standard Camera.

Performing automatic mapping from a very large range of values to a limited set of values while preserving the quality of image is in general an NP-Hard problem [14-15]; therefore, the use of metaheuristics is appropriate for such a complex problem. Metaheuristics are powerful nature-inspired stochastic computational algorithms that fall under the artificial intelligence umbrella; they work iteratively to solve complex problems by generating optimal or close-to-optimal solutions which cannot be resolved using traditional optimization methods [16]. Furthermore, metaheuristics do not require mathematical modelling of the problem to be optimized referred as a black-box problem [16]. Metaheuristics have been successfully used in image processing and various other applications [17]. In this work, we utilize a metaheuristic algorithm with a recently proposed TMO, referred by the authors as Adaptive Threshold vs Intensity based TMO, or ATT in short [18], to produce tone-mapped LDR images of high quality. The authors of ATT noted that performance of histogram based TMOs is heavily dependent on construction of the histogram bins. Therefore, they used a sensitivity model of HVS, referred as Threshold vs. Intensity (TVI) model [19] to form histogram bins mimicking the function of human eye. We start with the initial tone-mapping curve generated by the ATT in the form of a lookup table (LUT) and iteratively change the values using the differential evolution (DE) metaheuristic. The proposed optimization framework successfully enhances the quality of the tone-mapped results. Experimental evaluations are carried out on several test images of different types of content and dynamic range to test and evaluate the proposed optimized histogram-based approach, referred as OHbA hereinafter. The contributions of this paper are as follows:

- An optimized histogram-based approach is proposed that applies the DE optimizer on the histogram of the input HDR image to convert it *optimally* to an LDR image.
- The DE algorithm is tailored to the constraints of the TMO matching problem.

The rest of the paper is structured as follows. Section II reviews the related work. The proposed approach including the ATT algorithm and the optimization process is presented in Section III. Section IV provided a brief description of the metric employed for evaluation followed by the detailed presentation of experimental results. Finally, the paper is concluded in Section V.

II. Related Work

In this section, we review the works proposed previously in the domain of tone-mapping used for converting HDR images to the LDR counterparts. In this context, we classify the approaches and highlight the weaknesses and strong points of each approach.

Tone-mapping operators target a range of objectives while converting from HDR to LDR images, such as better visibility, natural color appearance, preservation of scene details, and photographic look, among others. The approaches for tone-mapping can be classified into two main groups, global and local. The main characteristics of the global operators is that they preserve the relative order of pixel luminance values by using a monotonically non-decreasing mapping curve. On the other hand, local operators use neighborhood features to determine the value of LDR luminance, and therefore the relative order of pixel intensities is not necessarily maintained. Local operators can show more details in the LDR images, but they are prone to artefacts which can affect their visual appeal [20]. Table I summarizes the difference and highlights the advantages of each group.

Some interactive tone-mapping techniques have also been developed. They determine areas of interest using different methods such as the position of cursor or gaze of user. The authors of the work [21] proposed a method that enables users to define some boundaries on a given image and controls the details of the defined area by adjusting the tonal values. A tool designed for interactive display was presented in [22], where the main objective is to grant users the control on the level of contrast. A system presented in [23] detects the area that falls in the user's gaze by using an eye tracker and uses the contents in the area to tune the tone-mapping parameters in real-time. The system mimics the adaptation mechanism of the human eye to a wide range of brightness levels. A similar work in [24] also relies on the user's gaze, but the final objective here is to improve the performance, i.e., the speed of operation.

A biological retina model is used in [25] for tone-mapping. The main feature of this work is the use of spatial-temporal filtering for two main purposes – reducing the noise and enhancing the temporal stability. In [26], a median based approach is proposed. The key goal is to make localized environmental adaptation to generate image appearance calibration. Targeting the video domain, the authors of [27] provided a post-processing approach, where the final objective is to ensure temporal stability for static TMOs. In the time domain, Ferwerda et al. [28] presented a visual adaptation model for tone mapping. They depend on visibility, color appearance, and sensitivity, which are adjusted according to some thresholds. Aiming at saving contrasts and details, the authors of [29] provided a scene dependent basis, where compression of luminance is employed within the scene. Based on both the photographic look and photographer response respectively, the authors of [30-31] provided some new methods that use human eyes' sensitivity to achieve tone mapping.

TABLE I. Comparison of Global and Local TMOs

Term	Global TMOs	Local TMOs
Difference	Rely basically on the value of luminance only for the mapping process.	Take properties of the neighboring pixels also into consideration in the mapping process.
Main advantage	Use a non-decreasing monotonic curve in the mapping process, and thus they are computationally efficient.	Perform well when it comes to reproducing fine details.
Main disadvantage	Important details can be missed out in the process of mapping to LDR.	Enhancement of details often leads to creation of visible artefacts.

Since the human visual sensitivity follows the Gaussian distribution, Kim and Kuatz [32] proposed an average of scene's log luminance-based method to perform the tone mapping. Within the two-dimensional and three-dimensional spaces, the authors of [33] modeled the tone mapping curves using the normalization of the RGB color space to mitigate the distortions in the color contrasts. A good level of improvement was achieved in the tone-mapped images in [34-35]. The key idea of enhancement in [34] is relying on the preference model of human viewer, while in [35] the improvement is achieved through utilizing weighted least square filters and artificial intelligent method, i.e. a neural network, to preserve colors while shifting the luminance. The authors of [36] proposed a psychophysical based TMO method, which depends on both the color appearance and visual acuity. As for the response, this method is relying on quantifying of threshold visibility. In a similar method, the authors of [37] proposed a mapping algorithm that depends on both the appearance and the psychophysical model. The main difference between the two is that in [37] smoothing filters are used to simulate the adaptation. The goal of the approach presented in [38] is to preserve the contrast in the HDR image. This is linked with temporal variation problem, which is solved by using filters. The authors of [18, 39] used an adaptation model of the human eye to the luminance levels. A histogram of non-uniform bins was constructed and used for tone-mapping which produced results better than traditional histogram-based methods.

Artificial Intelligence (AI) is employed in the domain of converting HDR images to LDR ones. In this context, some other recent tone-mapping algorithms proposed for better visual quality using different techniques such as deep learning and various HVS models, and some implementations on the hardware for real-time performance, as described below.

The researchers in the work [40] proposed a method that tries to solve the mapping problem by keeping the pixel counts in histogram bins within determined lower and upper ranges.

Building of histogram can be a slow manipulation when image size is huge. In this context, Scheuermann et al. [41] presented an effective programming of histogram construction on the graphical Processing Unites (GPUs) and applied this for to tone-mapping algorithm of Larson et al. [40]. In addition, Khan et al. [42] executed their algorithm on the GPUs and provided a real-time performance report even for the images of huge sizes. Moreover, Ambalathankandy et al. [43] executed a local histogram equalization method for tone-mapping on FPGA with poor specifications (i.e., small memory and minimal data access requirements).

Recently Rana et al. [44] provided a Deep Convolutional Neural Network (DCNN) for tone-mapping of HDR images. The researchers gathered a large group of tone-mapped images generated by a number of existing TMOs. For each input HDR image, the outputs of all TMOs were evaluated (in terms of comparison) relying on goal quality index. Then, the one that got the best band was involved in the training phase. The deep TMO trained depending on the previous gathered set of images would supposedly learn the best characteristics of all TMOs. This reflects that the perform is better than the existing TMOs. The experimental results showed by the researchers seem to ensure this assumption. That is because the deep TMO got the best average quality score during the testing phase.

It is worth mentioning that the AI-based techniques suffer from some issues related to security and privacy [45-52], which are considered out of scope in this work.

III. Proposed Optimized Histogram-based Approach (OHbA)

In this section, we introduce our proposed approach called Optimized Histogram-based Approach, OHbA, which takes an HDR image as input and converts it into an LDR image. Our proposed approach relies on optimization of the initial solution provided by the ATT algorithm. The initial histogram of the input image constructed by the ATT method is optimized to generate an LDR image of high quality. The flowchart given in Fig. 3 illustrates the steps of the proposed approach which are explained below in detail.

A. Histogram-Based Tone-Mapping

Recently, a new histogram-based tone-mapping algorithm, referred as ATT by the authors, has been proposed modifying an earlier histogram-based design [53], and it outperformed the existing state-of-the-art methods in several subjective and objective studies reported by the authors [18]. Our proposed optimization algorithm takes the transformation curve of ATT as one of the initial solutions and uses DE to improve it for better results quality. The reason behind selecting this histogram-based algorithm is that it does not require any user-defined parameters or human intervention. Our optimization module iteratively improves the quality of results by refining the histogram bins, thus changing the clustering of the HDR pixels and hence their corresponding LDR values.

The ATT algorithm starts by constructing the luminance channel from the RGB channels of the HDR image as:

$$HDR_L = 0.265R + 0.670G + 0.065B \quad (1)$$

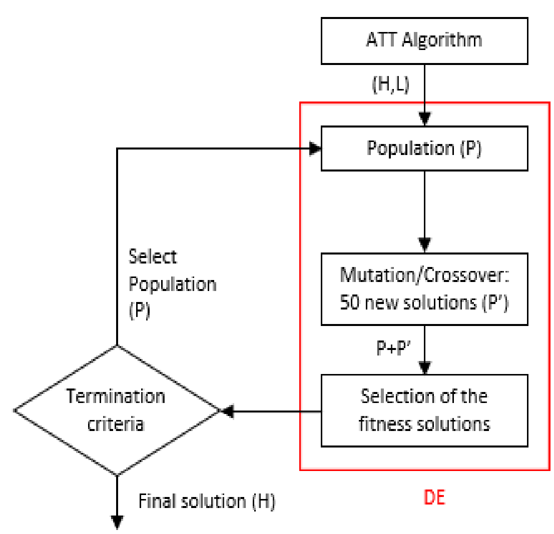

Fig. 3. Flowchart of the Proposed Approach for Designing an Optimization-based Tone-Mapping Operator.

Then, it designs a suitable tone-mapping curve based on histogram of this channel. The bins of the histogram are formed based on the TVI curve-based sensitivity model of the HVS [40]. The TVI curve describes sensitivity of the human eye as function of the environmental light conditions and can be used to calculate just noticeable difference (JND) under different viewing conditions. A JND is the minimum difference in brightness in the given viewing environment that would be noticeable to the average human observer. ATT determines widths of the histogram bins such that the luminance range spanned by each of them is the same if measured as the number of JNDs it covers. After constructing the histogram, the tone-mapping curve is designed based on a scaled version of the cumulative histogram in [0, 255] range. Histogram-based methods are known to suffer from excessive compression of low-density clusters of pixels and exaggerated enhancement of high-density clusters. The ATT algorithm refines the bin counts, again using the TVI model of HVS, to resolve these issues. This step determines the bins that are visually richer in terms of the number of perceptually distinguishable pixels and assigns them additional weights to ensure that the display levels are not allocated to the bins just based on the density of pixels.

The tone-mapping function of ATT can be represented by an LUT of 2 columns. The first column contains the HDR values H at the boundaries of the histogram bins, while the corresponding LDR values L are placed in the second column. These are essentially the values of the normalized cumulative histogram at the bin edges. It should be mentioned that traditionally the histograms use bins of equal width. However, as mentioned above, the ATT method forms non-uniform bins using the TVI model of the sensitivity of human visual system. As a result, clusters of visually similar pixels are formed and mapped to same or nearly same LDR values, generating visually *pleasing* output images.

The HDR and LDR pairs, H and L, in the LUT are the initial guess of tone-mapping parameters as indicated in the flowchart of our tone-mapping structure shown in Fig. 3. The process of linear interpolation with the LUT is used to tone-map the HDR image to LDR. Through the DE optimization process, stated next in this section, we iteratively modify the LUT. To simplify the process, we modify the initial LUT produced by the ATT such that the LDR values L are fixed at {0, 1, 2, …, 255} and the corresponding HDR values H are found through linear interpolation. In the modified LUT, the DE algorithm need to change the vector H only, which would mean changing the *ranges* of the histogram bins and hence changing the tone-mapping function.

B. *Differential Evolution*

Differential Evolution [54, 55] is one of the most robust population-based evolutionary algorithms which improves, via an iterative process, a group of candidate solutions, called a population, through classical evolutionary operators, namely, selection, crossover, and mutation. As explained in the pseudo code (Algorithm 1), in every iteration of DE, the best solutions are selected for next iteration. Then, this group of candidate solutions is utilized for the crossover and mutation to build new candidate solutions (offsprings). This intelligent and iterative stochastic process continues until reaching the stop criteria, i.e., the maximum number of iterations, or the minimum level of desired quality in one or more offsprings.

A large number of well-known optimization problems have been solved by DE. It has been used in applications such as privacy protection, high performance computing, image processing, security and data mining tasks to name a few. An extensive survey of DE can be found in [56]. In this work, we use DE to optimize the H vector obtained from the ATT design mentioned above, which is passed to the DE optimizer as one of the initial solutions. Algorithm 1 outlines the pseudo code of the proposed DE.

Algorithm 1: Differential Evolution Pseudo Code

1. Evaluate the initial population P of size NP composed of random individuals and the solution H.
2. While Nb iterations < Max. Nb. Iterations, do:
   - 2.1. For each individual Pi (i = 1, . . ., NP) from P, repeat:
     - (a) Generate candidate C from parent Pi using crossover and mutation
     - (b) Evaluate the candidate C: TMQI (C)
     - (c) If the candidate is better than the parent, the candidate replaces the parent.
       If the parent is better than the candidate, the candidate is discarded. Otherwise, the candidate is added in the population.
   - 2.2. If the population has more individuals than NP, truncate it.

end.

The initial solution H is used to improve the tone-mapping of the given HDR image, and the quality of the LDR image, used for comparison purposes by DE, is measured using the Tone Mapping Quality Index (TMQI) [57], which is widely used for this purpose in the existing literature and is described later in this paper in more detail. The vectors H are evaluated at every iteration by DE using the measured TMQI values. Each iteration modifies the vectors H such that the TMQI values of the produced LDR images are ideally larger (better) than the values obtained in the previous loop.

The optimization problem, in this work, is composed of 255 variables representing the range of every bin. The problem can be modeled as a maximization problem of the quality LDR image as shown below.

$$\text{Maximize } F(H) = \text{TMQI (LDR)} \tag{2}$$

s.t.

$$x_i < x_{i+1,} = 1,2,\ldots,255 \tag{3}$$

where x_i is the upper boundary of bin b_i defined by H.

It should be noted that the bin edges in vector H are sorted floating-point values in ascending order. The original DE algorithm does not require the vector to be sorted; however, we modify it to enforce this constraint. This reduces the search space of the optimizer which leads to a faster convergence. Minimum and maximum values of H are known for a given HDR image and these constrained are also applied.

Based on our preliminary experiments we have found that the following parameters settings for the DE algorithm are more appropriate for the studied problem:

- Amplification factor, F = 0.5
- Crossover rate, Cr = 0.5
- Value-to-reach (VTR) : 1.0
- Population size = 50
- Max. Number of iterations = 200

The iterative optimization process mentioned above incrementally enhances the quality of the output images in each iteration. In most of the cases, the enhancement beyond 200 iterations is minimal. Therefore, we set the stop condition to 200 iterations or the minimum desirable value of TMQI, whichever is achieved first. Fig. 4 shows the progressive improvement in the quality (TMQI index) of the LDR images for 10 different HDR test images described in Table II. A gradual improvement over iterations of every image is represented by a distinctive curve in the figure.

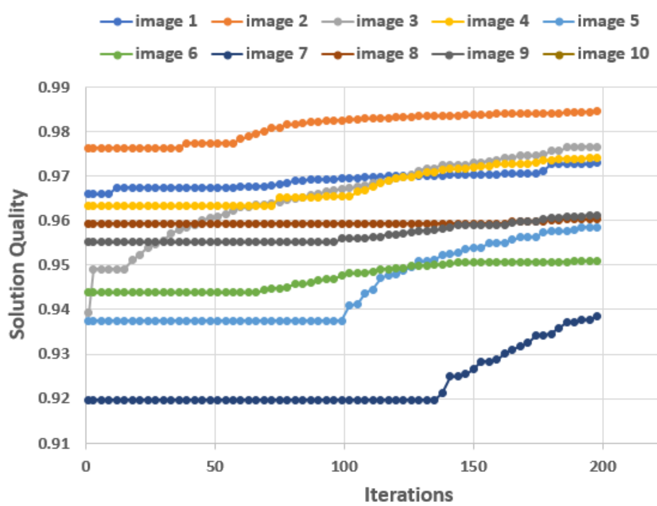

Fig. 4. DE Quality Improvement Over Time for the 10 Images Obtained from the ref [59].

IV. Experimental Results Evaluations

In this section, we show experimental results comparing the proposed design with some state of the art existing TMOs. We present quantitative evaluations using the TMQI metric which is also explained briefly in this section.

A. Tone-Mapping Quality Index

For evaluation purposes, we rely on the metric called tone-mapped image quality index, TMQI. The TMQI metric is used to measure the structural similarity as well as the naturalness, which in turn quantify the quality of the output images in [0, 1] range. The higher value of the TMQI means a higher quality and vice versa. The naturalness index of TMQI gives useful information about the correlations between image naturalness and different image attributes [57]. It is defined by the following formula.

$$N = \frac{(P_G \times P_\beta)}{NoR} \tag{4}$$

where, P_G and P_β are the Gaussian and the Beta probability density functions, respectively. NoR is the normalization factor. As for structural similarity index, TMQI calculates the local similarities between corresponding patches a and b of HDR and LDR image pairs using the following formula.

$$S_{Local} = \frac{2 \times y_a \times y_b + C_1}{y_a^2 + y_b^2 + C_1} \times \frac{y_{ab} + C_2}{y_a \times y_b + C_2} \tag{5}$$

where, $y_a . y_b . and\ y_{ab}$ are the local standard deviations and the cross correlation between the corresponding HDR and LDR patches. $C_1\ and\ C_2$ are the positive stabilizing constants.

The overall TMQI is the combination of the previous two metrics and is defined as.

$$\text{TMQI} = \mu S_{local}^{\alpha} + (1 - \mu) \times N^{\rho} \tag{6}$$

where, $0 < \mu < 1$ adjusts the relative importance of the two components (i.e., naturalness and structural similarity), and α and ρ determine their respective sensitivities.

B. Comparitive Studies

For comparison, we selected three representative tone-mapping algorithms. The global TMO by Reinhard et al. [26] is the most well-known and extensively used algorithm which has been shown to produce natural looking results. ATT [18] is a recent algorithm which was used as the initial solution for our optimization loop. ATT outperformed all other algorithms in the extensive objective and subjective studies reported in [18]. The algorithm by Liang et al. [58] is a recent algorithm and authors have reported high quality results outperforming many existing methods. The experiments reported below were conducted on a computer equipped with Intel i5 1.4 GHz CPU and 4 GB 1600 MHz DDR3 RAM, running on OS X Yosemite.

In Tables II and III we show the TMQI scores obtained by the output images produced by these methods. The 10 test images used in Table II are encoded in the well-know HDR format, RGBE, and are picked randomly from the public dataset available at [59]. The images used in Table III are the complete dataset of the HDR images taken from the accompanying DVD of [60] encoded in another famous HDR format, OpenEXR. It can be seen that for both sets of images, the proposed TMO obtained highest scores compared to the existing state of the art methods.

As shown in Table II, the proposed OHbA method achieved the most accurate results for 9/10 images and remained at the second position for one image by a small margin. In Table III, the OHbA achieved the most accurate results for 7/10 images and remained at the second position for remaining 3 images by a small margin. In all the cases, the OHbA outperformed the original solution generated by the ATT which shows the efficiency of the optimization methods and its benefits in HDR to LDR conversion applications.

TABLE II. TMQI SCORES USING RGBE TEST IMAGES. THE HIGHEST SCORE FOR EACH IMAGE IS SHOWN IN BOLD FONT

Image	ATT	Reinhard	Liang	OHbA
Tree_oAC1	0.965972	0.8464	0.9405	**0.972941**
SpheronPriceWestern_o264	0.976255	0.8046	0.9263	**0.984437**
dani_synagogue_o367	0.939193	0.8067	0.8886	**0.976596**
rend13_o7B0	0.963167	0.6644	0.6925	**0.974154**
rend09_o2F3	0.937495	0.7358	0.8276	**0.958563**
dani_cathedral_obbc	0.943863	0.7745	0.9093	**0.950933**
'big Fog Map _oDAA	0.919781	0.7713	**0.9589**	0.938423
Display1000_float_o446	0.959306	0.7638	0.8671	**0.960383**
rend01_oBA3	0.939071	0.8514	0.7801	**0.950052**
Desk_oBA2	0.955078	0.8091	0.9002	**0.961133**

TABLE III. TMQI RESULTS USING OPENEXR TEST IMAGES. THE HIGHEST SCORE FOR EACH IMAGE IS SHOWN IN BOLD FONT.

Image	ATT	Reinhard	Liang	OHbA
Bristol Bridge	0.821403	0.7258	**0.8650**	0.845697
Clock Building	0.941914	0.7932	0.9117	**0.954487**
Crow Foot Glacier	0.940239	0.7693	0.9569	**0.973385**
Dome Building	0.887815	0.7480	0.8064	**0.913858**
Fribourg Gate	0.946435	0.7932	**0.9752**	0.970729
Montreal Store	0.965380	0.7865	0.8684	**0.970606**
Moraine2	0.900711	0.7645	**0.9438**	0.927393
Street Lamp	0.971495	0.7930	0.9403	**0.978722**
Vernicular	0.948842	0.7834	0.9667	**0.976041**

V. CONCLUSION

The images of high dynamic range cannot be viewed with full details on the existing displays, because the range of the screens is much less than of the captured images. In other words, the problem of converting high dynamic ranges images into low dynamic range images is pressing, to enhance the visualizing experience taking advantage of the advancements in imaging technologies. Many approaches were proposed previously to deal with this issue. However, artificial intelligence was not used in this domain to the best of our knowledge. Based on the DE algorithm, which forms the base of optimization of the output images' quality, we propose the optimized histogram-based approach (OHbA). The OHbA enhances the quality of images for all the studies cases. Compared with an existing state of the art tone-mapping algorithms, the proposed approach shows better performance based on the quality metric called tone-mapped quality index (TMQI).

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Self Organising Fuzzy Logic Classifier for Predicting Type-2 Diabetes Mellitus using ACO-ANN

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***Abstract*—In today's digital world, a dataset with large number of attributes has a curse of dimensionality where the computation time grows exponentially with the number of dimensions. To overcome the problem of computation time and space, appropriate method of feature selection can be developed using metaheuristic approaches. The aim of this work is to investigate the use of ant colony optimization with the help of neural network to select near optimal feature subset and integrate it with the self-organizing fuzzy logic classifier for improving the recognition rate. The proposed fuzzy classifier derives prototype from the collected data through an offline training process and uses it to develop a fuzzy inference system for classification. Once trained, it can continuously learn from streaming data and later adapts the changing facts by updating the system structure recursively. The developed model is not based on predefined parameters used in the data generation model but is derived from the empirically observed data.**

Keywords—Ant colony optimization; feature selection; fuzzy logic classifier; self organizing; type-2 diabetes mellitus

I. Introduction

Machine learning algorithms are widely used in medical field. Several classification and clustering techniques are useful for disease prediction. Nowadays, we are living in the era of BIG-DATA, so classification algorithms have got importance in the research. Conventional classification algorithms are trained on static datasets. Once the classifiers are trained, no modification is possible in their configuration.

Most of the classifiers are developed when data is not available in the largescale. To overcome this issue, online approach can be used for developing classifiers. In this approach classifiers are constantly learning from new instances [1]. They also store key information and disposes already processed instances. Variation in the pattern in nonstationary situations is considered by evolving system structure and recursively modifying meta – data. Pattern may change when the data availability is continuously increasing, and conventional offline approaches will not consider this fact. However, it is not feasible to learn online from the beginning because setting the system with the presented static data in an offline manner can assure improved performance. SOF classifier is trained in two stages. The classifier is trained offline with the presented static data and fuzzy rule-based system is obtained in the first stage. During the second online training stage, the fuzzy rule-based system recognized over the offline training process will be restructured after the new instances are processed to track the possible changes in the data pattern [1] [2].

Our study is based on the development of predictive model for Type-2 diabetes Mellitus (T2DM). Diabetes is a chronic illness accountable for increasing number of deaths every year around the world. It typically progresses after years of insulin resistance, or prediabetes. Prediabetes can progress to diabetes when liver and muscle cells become more and more insulin resistant (they don't respond properly to this internal insulin signal) and have growing problems of increased sugar in the bloodstream. Physicians suggest that if prediabetes is recognized early its progression can be halted. As per physician's advice, vegetables and fruits should form the bulk of the diet, losing weight and exercising are the best ways to stop prediabetes from becoming Type 2 diabetes. If prediabetic stage is not treated it can lead to type 2 diabetes and complications like heart disease, renal disease and stroke. Machine learning algorithms can be used to develop a predictive model for T2DM [3]. If prediabetic stage is detected on time, then change in lifestyle can prevent the diabetes.

I have selected this topic because the current approaches have often classified the patients as either having diabetes or a healthy individual, ignoring the prediabetic state of a patient. This leads to increased incidence of diabetes if no proper preventive measures are taken on time. It can be curbed at the prediabetic stage by introducing lifestyle changes.

Most of the work available in the literature has been done on PIMA dataset of the UCI repository. This dataset has 8 attributes and only two labels (Healthy / Diabetic). There is no mention of prediabetic stage and hence I have selected this topic.

Literature review shows that most of the developed traditional classifiers are offline [3] [4] [5] Once they are trained on dataset which is static in nature then no further modification is possible in the structure of classifier model. These traditional methodologies require users to predefine various kinds of parameters to obtain promising result. In real cases this prior knowledge may not be available. The recent study shows that most of the work has been done on offline data processing and retraining is required when data pattern changes. In our study, we have overcome this limitation and taken into consideration changing data pattern while developing the predictive model.

This paper is presented by writing five sections. Section one gives the introduction of reasons behind the selection of study. Section two discusses the empirical data analytics operators in brief. Section three discusses the feature selection method. The pseudocode of stage 1 (static offline training) and stage 2 classifier (self-evolving training) has also been discussed in section three. Section four comprises of the analysis and experimental results. Section five contains conclusion of the experimental study.

II. Notional Basis

Below mentioned statistical calculations are required for the proposed method [2]:

1) Cumulative proximity,

2) Unimodal density,

3) Multimodal density,

4) Along with these proximity and density calculation, we need to compute their recursive forms for streaming data processing.

a) Cumulative proximity- The cumulative proximity between two data points is computed by the equation 1.

$$\pi_{k(x_i)} = \sum_{j=1}^{k} d^2\left(x_{i,}\, x_j\right); i = 1,2, \dots, k \tag{1}$$

Where, d (x_i, x_j) denotes the distance between two points which can be measured as Euclidean, Makowski or Cosine.

b) Unimodal density- This specifies the main data pattern in our proposed method and computed by the equation 2.

$$D_k(x_i) = \frac{\sum_{l=1}^{k} \pi_k(x_l)}{2K\pi_k(x_i)} = \frac{\sum_{l=1}^{k}\sum_{j=1}^{k} d^2\left(x_l\,,\, x_j\right)}{2k\sum_{j=1}^{k} d^2\left(x_i\,,\, x_j\right)};$$

$$i = 1,2, \dots, k \tag{2}$$

c) Multimodal density- This is calculated by the equation 3 where, f_i specifies the corresponding frequency of occurrence.

$$D_k^{MM}(u_i) = f_i D_k(u_i) = f_i \frac{\sum_{l=1}^{k} \pi_k\,(x_i)}{2K\pi_k(u_i)}; i = 1,2, \dots, U_k \tag{3}$$

d) Recursive computation of densities - The recursive computation has a substantial role in the second stage of developing SOF classifier. We get well-designed recursive calculation forms, using the equation 4 where quantities can be updated by an effective means by storing only the key meta-parameters.

$$\pi_k(x_i) = K\left((x_i - \mu_k)\textstyle\sum_k^{-1}(x_i - \mu_k)^T + X_k - \mu_k \sum_k^{-1} \mu_k^T\right) \tag{4}$$

Where, recursive definitions of global mean μ_k, covariance matrix $\sum_k$ and X_k are computed by equation 5, 6 and 7, respectively.

$$\mu_k = \frac{K-1}{K}\,\mu_{K-1} + \frac{1}{K}\,x_K;\ \mu_1 = x_1 \tag{5}$$

$$X_K = \frac{K-1}{K} X_{K-1} + \frac{1}{K} x_K^T x_K;\ X_1 = x_1^T x_1 \tag{6}$$

$$\textstyle\sum_K = \frac{K}{K-1}(X_K - \mu_K^T \mu_K) \tag{7}$$

III. Proposed Methodology

In this experimental study we have investigated the use of ant colony optimization with the help of artificial neural network (ACO-ANN) to select near optimal feature subset and integrated it with the self-organizing fuzzy logic classifier for improving the recognition rate.

In this study, we have proposed Ant Colony Optimization method for feature selection [4] and ANN is used for implementing fitness function. The obtained feature subset is then further used for developing SOF classifier. The architecture diagram of proposed system is depicted in Fig. 1. Literature shows that there are various machine learning algorithms [6], metaheuristic algorithms [7] [8] and fuzzy logic methods [9] which can be used for feature selection. Based on literature survey feature selection using nature inspired algorithms Ant colony optimization gives higher accuracy [5]. ACO is inspired by the behaviour of ant colonies. When ants go for searching food, they deposit pheromone on the path. This odorous substance is used as a communication medium. The quantity of the placed pheromone depends on the distance of the food source. Other ants moving at random detects a laid pheromone and most likely the ant follows the same path. These ants will also place the pheromone. Consequently, the path which is used by more ants will be followed. Probability of path which ant decides to choose increases with the number of ants previously followed that path. An artificial ant builds solutions to an optimization problem. Hybrid algorithm was developed to select prominent features using ACO. An artificial ant can be used for selecting subset of features. Ants traverses the node which represents features to construct a subset. All the ants attempt to construct a subset. The conventional probabilistic transition rule for selecting features is used. The node is chosen based on the probability which is computed by equation 8.

$$P_{ij}^k = \begin{cases} \dfrac{\tau_{ij}^{\alpha} . \eta_{ij}^{\beta}}{\sum_{c_{il} \epsilon f(s^p)} \tau_{il}^{\alpha} . \eta_{il}^{\beta}} \ if\ c_{il} \epsilon f(s^p) \\ 0\ otherwise \end{cases} \tag{8}$$

Where, $f(s^p)$ represents the set of possible features which can be further added to the solution being constructed. τ_i denotes pheromone values and η_i denotes heuristic values related to feature i = 1,2,3…n. α and β are two constants which regulates the pheromone value and heuristic information respectively. At each iteration pheromone values τ_{ij}, is updated by all the ants and the updated values at every path (i , j) is computed by equation 9.

$$\tau_{ij} = (1-\rho)\tau_{ij} + \textstyle\sum_{k=1}^{m} \Delta\tau_{ij}^k \tag{9}$$

Where, ρ denotes rate of evaporation, m denotes number of an artificial ant and $\Delta\tau_{ij}^k$ is pheromone laid on path (i, j) by k^{th} artificial ant. Equation 10 computes $\Delta\tau_{ij}^k$.

$$\Delta\tau_{ij}^k = \begin{cases} \frac{Q}{f}\ if\ an\ ant\ used\ path\ (i,j) \\ 0\ otherwise \end{cases} \tag{10}$$

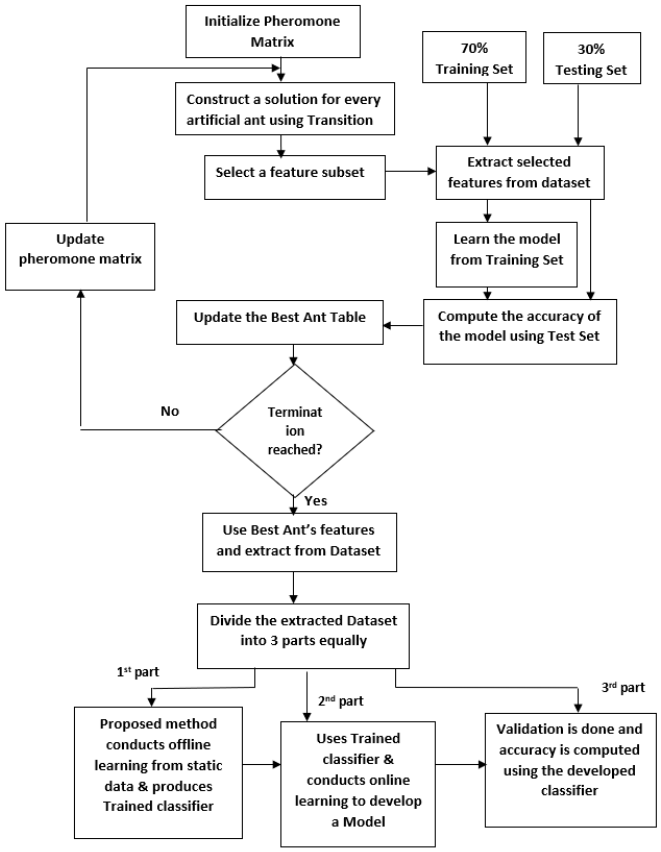

Fig. 1. Architecture of Proposed System.

Where, Q is constant, and f refers to the length of the tour by kth ant. Integrating ACO with Artificial neural network (ANN) so that important features are extracted and then SOF is employed for classification. ANN has been employed for developing fitness function of ACO [8].

SOF is implemented in two stages. SOF will learn from the static dataset available at the beginning and recognize prototypes from each class independently to form 0-order fuzzy rule created on the acknowledged samples per class [1]. There is no impact of training processes of one class on another. The training process is led on data examples of the cth class (C = 1,2, 3, …, N). Prototypes are recognized based on the distributions of the data samples and its density. Firstly, multimodal densities are computed using all distinct instances in a class by the equation 4.

Pseudocode for First stage of classifier (static offline)

1. Compute D^{MM} over all the unique samples for each class by equation 3.
2. Find r_1 by equation 11 $\{D^{MM}_{K^c} u^c_i\}$.
3. Delete r_1 from $\{u\}^c_{U^c_K}$.
4. K:= 1, {r}:= r_1, $D^{MM}_{K^c}(r) = D^{MM}_{K^c}(r_1)$
5. Repeat following until $u^c_k - k$ is not empty
   K++;
   Find r_k and delete it from $\{u\}^c_{U^c_K}$
   Add r_k to r i.e. {r} = {r} + r_k
   $\{D^{MM}_{K^c}(r)\} \leftarrow \{D^{MM}_{K^c}(r)\} + D^{MM}_{K^c}(r_k)$
6. Recognize $\{p\}_0$ by equation 12 and form data clouds around it.
7. Compute the center of the data clouds denoted by $\{\varphi\}_0$ and compute D^{MM} around it.
8. Find $\{\varphi\}^{neighbors}$ and $\{p\}^c$ by equation 13 and 14 respectively.
9. Generate cth fuzzy rule with $\{p\}^c$

$$r_1 = \arg\max_{i=1,2,\ldots,U^c_K}\left(D^{MM}_{K^c}(u^c_i)\right) \tag{11}$$

$$if \left\{\begin{matrix}(D^{MM}_{K^c}(r_i) > D^{MM}_{K^c}(r_{i+1}))\ and\ (D^{MM}_{K^c}(r_i) > D^{MM}_{K^c}(r_{i-1})) \\ then\ r_i \in \{p\}_0\end{matrix}\right\} \tag{12}$$

$$if\left(d^2(\varphi_{i,}\varphi_j) <= G^{c,L}_{k^c}\right) then\ (\varphi_j \in \{\varphi\}^{neighbours}_{\mathrm{i}}) \tag{13}$$

$$if\left(D^{M,M}_{k^c}(\varphi_i) > \max_{\varphi\in\{\varphi\}^{neighbours}_{\mathrm{i}}}\left(D^{M,M}_{k^c}(\varphi)\right)\right) then\ (\varphi_i \in \{p\}^c) \tag{14}$$

The data examples are ordered by their mutual distances and values of multimodal density and stored in{r}. Let r_1 be the highest multimodal density. r_2 is recognized as the instance with the minimum distance from r_1 and r_3 is identified based on the minimum distance from r_2. Reiterate in this way and build the list {r}. Multimodal densities are ordered and specified by $\left\{D^{MM}_{K^c}(r)\right\}$. Prototypes denoted by$\{P\}_0$ are then recognized as the local maxima of the ordered multimodal densities. Centers of the data cloud is computed and denoted by $\{\varphi\}_0$. $\{\varphi\}^{neighbours}_{\mathrm{i}}$) denotes the collection of the centers of the adjacent data clouds. After identifying all the representative prototypes of the cth class fuzzy rules are constructed.

$$if\ \left(D_{k^c+1}\left(x^c_{k^c+1}\right) > \max_{p\epsilon\{p^c\}}\left(D_{k^c+1}(P)\right)\right) or\ \left(D_{k^c+1}\left(x^c_{k^c+1}\right) > \min_{p\epsilon\{p^c\}}\left(D_{k^c+1}(P)\right)\left(D_{k^c+1}(P)\right)\right) then\ \left(x^c_{k^c+1}\ \epsilon\ \{p\}^c\right) \tag{15}$$

$$if\left(\min_{p\epsilon\{p^c\}} d^2\,(x^c_{k^c+1}, p)\right) > G^{c,L}_{K^c+1} then\ (x^c_{K^c+1} \in \{p\}^c) \tag{16}$$

During the second phase of training, the classifier continues to update its configuration on a sample basis when new data is provided. Like the offline training phase the set of fuzzy rules of different classes are adapted. When the K+1th sample of cth class is provided then the meta parameters $\mu^c_{K^c+1}$, $X^c_{K^c+1}$ and $\sum^c_{K^c+1}$ are computed by equations 5, 6 and 7, respectively.

Pseudocode for Stage-2 self-evolving training (online learning)

1. Repeat steps 2 – 7 until the new instance of Cth class $x^c_{K^c+1}$ is presented.
2. Compute $\mu^c_{K^c+1}$, $X^c_{K^c+1}$ and $\sum^c_{K^c+1}$ by equations 5, 6 and 7, respectively.
3. Compute D at $x^c_{K^c+1}$ and $\{p\}^c$;
4. Evaluate equations 15 and 16 and use Boolean OR between them.
5. If the result of OR operation between equations 15 and 16 is true then,
   $$++N^c;\ P^c_{N^c} = x^c_{k^{c+1}+1};\ S^c_{N^c} = 1;$$

$$\{p\}^c = \{p\}^c + P^c_{N^c} ;$$

Else

Compute $P^c_{n^*}$;

$$P^c_{n^*} = \frac{S^c_{N^*}}{S^c_{n^*}+1} P^c_{n^*} + \frac{1}{S^c_{n^*}+1} x^c_{K^c+1};$$

$$S^c_{n^*} = S^c_{n^*} + 1 ;$$

Endif

6. $++K^c$;
7. Update the fuzzy rule.

IV. Analysis and Experimental Results

For this study the dataset has been collected from the local hospitals. The dataset is having 32 features and 1071 instances. Class variable has three values as Diabetic, Prediabetic and Healthy patients. All the features are not useful for diabetes classification. ACO is used for selecting important features and objective function is developed using ANN for selecting near optimal feature subset. The selected features from the above ACO-ANN hybrid model are used for developing the Self organizing classifier. The proposed method uses Euclidean distance and cosine similarity for the implementation of classifier [10]. The dataset has been divided into three parts equally. Classifier conducts offline learning on the first part of static data. Then the proposed classifier conducts online learning from streaming data from second part of the collected dataset. classifier Third part is reserved for validation and testing purpose on unseen data. The developed classifier performs validation on testing data. ACO has selected Family History, Eating Fruits/Vegetables, PPG, FPG, Age, Feeling Hungry, Exercise, Frequent Urination, itchy skin and gender as important features in the diabetes detection. In this work values for ACO algorithm parameters are as per the Table I.

Confusion matrix on validation data for Euclidean distance and cosine similarity is shown in Fig. 2 and Fig. 3, respectively. The accuracy obtained is 86.27% in diabetes detection when distance type is Euclidean distance and 80.67% in the case of cosine similarity.

We have obtained the overall values for estimating the performance of the proposed classifier. Overall values of parameters obtained for the developed model are given in Table II. In our experimental study we have computed Accuracy, Error, Sensitivity, Specificity, Precision, False positive rate, F1 score, Matthew Correlation Coefficient and Kappa values to measure the performance. Users of the developed classifier would require the results of prediction. Practically, only the probability of correct predictions is not sufficient. Hence the set of statistical measures are computed to describe the developed classifier performances in various aspects. The following four terms are necessary to measure the various performance metrics:

- True positive (TP) - The data rows belong to the positive class and has been correctly predicted.
- False positive (FP) - The data rows belong to the negative class and has been incorrectly predicted as positive
- True negative (TN) - The data rows belong to the negative class and has been correctly predicted.

False negative (FN) - The data rows belong to the positive class and has been incorrectly predicted as negative. The below mentioned measures qualify the performance of the prediction model and are used in medicine to measure the accuracy of analytical procedure.

TABLE I. ACO Parameters and Values

Parameter	**Value**
Initial Pheromone τ_0	0.1
Pheromone Exponential Weight α	1
Heuristic Exponential Weight β	1
Evaporation rate ρ	0.06
Constant Q	1

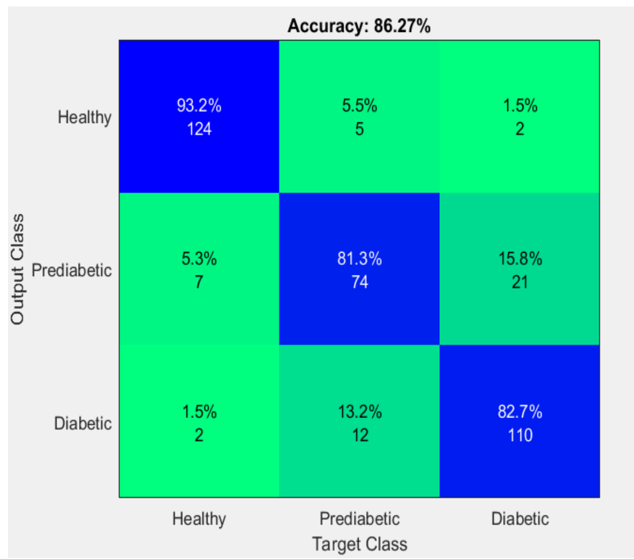

Fig. 2. Confusion Matrix on Validation Data (Euclidean Distance).

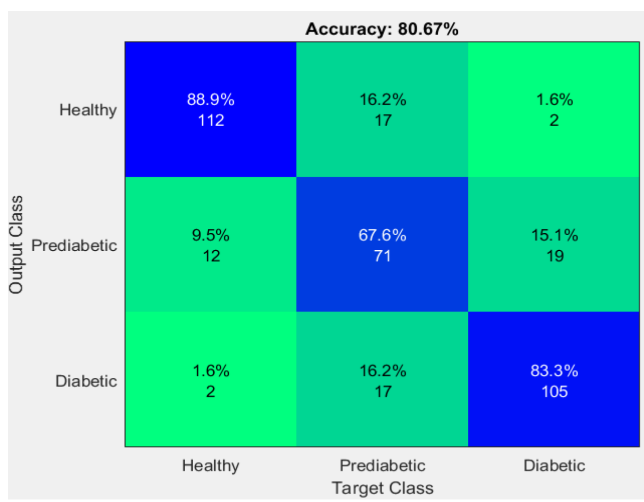

Fig. 3. Confusion Matrix on Validation Data (Cosine Similarity).

1) Accuracy: It is one of the most common evaluation measures to assess the performance of the model. Classification accuracy is given by the relation,

$$Accuracy = \frac{TP+TN}{TP+TN+FP+FN} * 100$$

2) Error rate- Error rate gives incorrect predictions on total.

$$Error\ rate = (1 - accuracy) = \frac{(FP + FN)}{(TP + TN + FP + FN)}$$

3) Sensitivity: The sensitivity is used to certify the test capability of the model. it is the probability that the test is positive on malignant subjects. Sensitivity is obtained as the number of true positive results over the number of actual positive cases. It is referred as true positive rate. It is also called as recall.

$$Sensitivity = \frac{TP}{TP + FN} * 100$$

4) Specificity: It refers to the true negative rate. A good predictive model is one that maximizes both sensitivity and specificity. We want model to be both sensitive and specific.

$$Specificity = \frac{TN}{FP + TN} * 100$$

5) Precision: It is also called as positive predicted value. It is the proportion of positive samples that are truly positive. Higher precision is better. It efficiently computes an overall posterior probability and hence it is a meaningful performance measure.

$$Precision = \frac{TP}{TP + FP}$$

6) False positive rate (FPR): FPR is the ratio of false positives to the total number of negatives.

$$(1 - specificity) = False\ positive\ rate = \frac{FP}{FP + TN}$$

7) F1_score: It combines precision and recall using harmonic mean. Harmonic mean is used precision and recall both are expressed as proportions between zero and one. The worst F1 score value is zero and best is one.

$$F1_{score} = \frac{2 * recall * precision}{recall + precision}$$

8) Matthew Correlation Coefficient (MCC): MCC characterizes a confusion matrix with a single value. An MCC coefficient value 1 signifies a perfect prediction, 0 signifies no better than random prediction and −1 indicates total disagreement between prediction and observation.

$$MCC = \frac{(TP * TN - FP * FN)}{(TP + FP) * (TP + FN) * (TN + FP) * (TN + FN)}$$

9) Kappa coefficient: Kappa Statistic compares the accuracy of the system to the accuracy of a random system. The Cohen's kappa coefficient is a statistical measure of inter-rater reliability. This coefficient is used to evaluate the classification accuracy. But it is normalized at the baseline of random chance on your dataset. In multi-class and imbalanced class problems, Cohen's kappa coefficient provides a good measure. Any kappa value less than 0.60 specifies inadequate agreement among the raters and less confidence should be shown in the study results.

$$Probability(Expected) = \frac{(TN + FP) * (TN + FN) + (FN + TP) * (FP + TP)}{Total * Total}$$

$$Kappa\ coefficient = \frac{Accuracy - Probability(Expected)}{1 - Probability(Expected)}$$

Multi-Class Confusion Matrix Output for the developed predictive model having distance type measure as Euclidean distance and cosine similarity is given in Table III.

TABLE II. STATISTICAL MEASURES OF DEVELOPED CLASSIFIER

S. No.	Parameters	Values (Euclidean Distance)	Values (Cosine similarity Measures)
1	Accuracy	86.27%	80.67%
2	Error rate	0.1373	0.1933
3	Sensitivity	85.31%	79.33%
4	Specificity	93.16%	90.49%
5	Precision	85.75%	79.95%
6	False Positive Rate	6.84%	9.51%
7	F1_score	0.8541	0.7992
8	Matthew Correlation Coefficient	0.7877	0.7039
9	Kappa	0.6912	0.5651

TABLE III. PREDICTIVE MODEL OUTPUT

	Class Value	True Positive	False Positive	False Negative	True Negative
Euclidean Distance	Healthy	124	9	7	217
	Prediabetic	74	17	28	238
	Diabetic	110	23	14	210
Cosine similarity	Healthy	112	14	19	212
	Prediabetic	71	34	31	221
	Diabetic	105	21	19	212

V. CONCLUSION AND FUTURE WORK

In this work, we have used metaheuristic approach for feature selection. ACO has been implemented to decide the features which can predict diabetes with higher accuracy. The proposed SOF Classifier algorithm does not depend on prior assumptions about the data generation model. But the proposed classifier learns from the static offline data and develops a prototype of Trained classifier. In the next stage the classifier conducts online learning from streaming data. The approach provides various types of similarity and distance measures. We have used Euclidean distance and cosine similarity as distance measure for evaluating the performance of the developed model. It has been observed that accuracy has been 86.27% when the distance mode is Euclidean distance. The observed accuracy was 80.67% in the case of cosine similarity. If the person has been classified as prediabetic by the developed predictive model, then consult your doctor for further treatment. Early intervention has been revealed to delay, and in some cases prevent, the progression from prediabetes to diabetes. The proposed method will help the individual from developing T2DM.

As future work, the developed model shall be considered for the extension of more metacharacters in the construction of stage1 classifier and for other classification problems. Further application of first order fuzzy rules in the SOF classifier will increase the degrees of freedom and therefore enhance the efficiency of the developed model. Different types of distance metrics like Manhattan, Minkowski, Hamming distance will be used for the implementation of classifier and comparison with the existing result.

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Modeling of a Tourism Group Decision Support System using Risk Analysis based Knowledge Base

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***Abstract*—The increasing number of tourist destination becomes the main factor for export earning, job vacancy, business development, and infrastructure. The problem that occurs is the difference in regional income (GDP) that is quite significant in each region. Thus, it is necessary for the government to make a decision or policy in increasing tourist visits, mainly in Bali. In this case, choosing the most efficient decision from a number of decisions is for the government, tourists, community leaders, academics, and entrepreneurs in the tourism sector, especially in Bali. It is important to have a *modeling decision support group* (GDSS). GDSS modeling by integrating a knowledge-based (KB) risk analysis can determine decisions, extract information, and identify problems in the tourism sector especially, tourism objects in each region, more specifically. Problem identification in risk analysis modeling is determining decisions in handling risks and finding solutions from alternative tourism decisions that are potentially enlarged and knowledge gained from each decision-maker (DM). The process of identifying knowledge starts with comparing the assessment criteria on each tourism object and knowledge of tourism decision-makers. The results of GDSS modeling are subsequently integrated into knowledge-based risk analysis so that a decision is obtained in the form of an impact or risk and solution or recommendation in developing the specified tourism object. The purpose of combining the result is to understand the impacts or risks that may arise, and recommendations recommended so that the impacts or risks can be avoided.**

Keywords*—GDSS modeling; risk analysis; tourism site; knowledge base; Bali tourism

I. Introduction

The development of tourism sector in Indonesia, especially in Bali, makes tourism sector as a significant factor in export earning, job creation, business development, and infrastructure. Tourism has gotten continuous expansion and diversification, becoming one of the most significant and fastest-growing economic sectors in Bali and increasing every year [1], [2], became the biggest income in the area. For foreign exchange earnings from each of the main sectors in Indonesia, tourism is in the fourth position after oil & gas, coal, and palm oil [2], and the sector's income continues to increase every year. Even though the global crisis has occurred several times, the number of international tourist trips shows growth. Data from UNWTO World Tourism Barometer shows that the number of tourist visits every year is increasing [3], and following the growth of world population.

The problem is that the number of tourist visits in each region is different, causing a gap in income from the tourism sector [4], and public sector development depends on the area. Different Local Own Revenues (PAD) in each district has an impact on the development of public facilities such as roads, sidewalks, street lighting, integrated parks, and others. One of the policies applied is to increase the potential of each tourist attraction in each region to attract tourists visiting them. The increasing number of tourist visits can add an income of the region The policy made by tourism office has not only an impact on the tourist area, but also an extensive influence on stakeholders engaged in tourism such as travel agents, hotel & villa businesses, restaurants, minimarkets, and the economy of surrounding communities [5], [6], associated with an increase in the tourism sector. The government policy determines to make decision recommendations and impacts of risks by combining opinions and thoughts of decision-makers using Group Decision Support System (GDSS) modeling. GDSS modeling is a system that can be used to support the meeting of a group of people who interact with each other in accomplishing a job [7]–[10], from several people with different skills.

GDSS modeling uses AHP method to determine alternative individual decisions [11]–[14], while for the incorporation of alternative individual decisions into group decisions use BORDA method [11], [15], [16] which is one of the GDSS models, ranks voting preferentially. GDSS method can make a decision that accommodates alternative decisions from decision-makers [17]–[19], according to the preferences given by the decision maker. AHP method is to combine logic for quantitative and qualitative data, experience, insight, and intuition, and can be implemented into an algorithm [20], [21], and the depth of the hierarchical structure which makes the model calculation more detailed. Thus, it allows decision-makers to find each criterion's weight and the level of comparison among the alternatives, especially in the tourism sector [12], [14], based on an assessment of the preferences of each decision maker. Because GDSS modeling only obtains alternative tourism selection decisions following the preferences of each DM, the risk of determining these alternatives is unknown. Before incorporating risk analysis into GDSS modeling, it can show the risks of alternative group decision choices and decision recommendations given through expert knowledge in tourism. This knowledge is implemented into knowledge-based (KB) method integrated with risk analysis.

Business risk analysis is determined based on the results of the GDSS approach and knowledge base, which aims to understand the risks and recommendations fully so that a solution can be determined. The results of alternative group decisions are then integrated with knowledge-base to support problem-solving [22], especially in the field of tourism business. A knowledge-based risk analysis model aims to help users make decisions on the risk assessment of attractions and provide a solution to the risks. The knowledge obtained is from several decision-makers (DM) or tourism decision-makers [23], [24], who understand about Bali tourism. There are ten individual decision-makers (DM) assessing each alternative tourism object. Each DM is translated into five groups, including Tourist DM, Government DM, Business DM, Academic DM, and Community DM. Each alternative tourist attraction has different criteria from one another, as well as a DM assessment of each alternative tourist attraction. Differences in assessment then become new knowledge in assessing a tourist attraction.

GDSS modeling with knowledge-based risk analysis can be an input for the Bali government to develop Bali tourism. GDSS modeling for Bali tourism can explain the influence of sub-model on tourist visits and find out factors that can increase the potential of tourism objects. This study describes building a GDSS Modeling using three main components, namely GDSS, Risk Analysis, and Knowledge Base, which are devoted to the development of tourism in the Bali area.

II. Related Works

Researches related to the Business Intelligence (BI) system model, associated with the integration of several sub-models in the field of tourism. The research uses a BI approach with the integration of Geographic Information Systems (GIS), Smart Data Location (SDL) and Smart Tourism Systems (STS) models, conducted by [25] with a case study of the "Angels for Travelers" tourist website Social Network Service. The results of the study aim to facilitate the relationship between tourist services with tourist actors (touristic operators, travel agents, citizens, etc.) in an STS platform.

Another approach [26] uses the variable destination framework and web navigation for tourism in Sweden. This research aims to build a BI Application framework integrated with the knowledge destination framework. The system obtains knowledge from tourist destination indicators that measure destination performance and tourist experience, gaining new knowledge from the customer-based destination process. Further research development was carried out with the Åre Destination Management Information System (DMIS-Åre) [27], aimed at studying tourist habits. Research using BI tools integrated with tourism destinations, web monitors, web mining, and web analytics aims [28], to determine tourist habits. Research integrates the BI system with information systems and eco-tourism [29] by utilizing BI system applications. The BI tool used is CRISP-DM for Ecotourism in Colombia to know the habits of tourists in cyberspace. Another approach was taken by [30], who integrated BI with BIG data and e-tourism. Enables companies to make time-sensitive and analytical BI process actions.

Further research about the extraction of knowledge at tourist destinations [31] divided into several components. This research proposes a new approach to the extraction of knowledge based on business intelligence and decision support for tourism purposes. This approach consists of (a) data models, (b) mechanisms for extracting data, and (c) analytical methods to identify important relationships and patterns across different business processes, giving rise to new knowledge. Research related to data processing uses the application of BIG Data techniques with the aim of mapping the application of BI to various data architectures [32] which aims to dig more profound knowledge. Integrates BI with Database Management, Business Analytics, Business Performance Management, and Data Visualization Components [33] will produce decisions with various scientific perspectives. The purpose of the knowledge gained is to provide feedback to festival organizers, so as to retain visitors for upcoming events.

In this study, the topic discussed is the Modeling of a Tourism Group Decision Support System Using a Risk Analysis Based Knowledge Base, consisting of several models integrated therein. The first sub-model is the Group Decision Support System, used to determine alternative group decisions from several tourism stakeholders. The method used is the Borda method and the determination of alternative individual decisions with the AHP method. The second sub-model consists of risk analysis to determine the level of risk inherent in these attractions. The risk analysis sub-model is also integrated with the knowledge base, so the decision results are from several relevant experts. Some of the sub-models above produce values that vary from one model to another. The integration of the three sub-models can provide government policy directions based on existing problems in the field.

III. Methodology

In this research, the main focus of risk analysis is more on the impact of risks from attractions and on tourist visits. The determination of risk analysis is based on alternative group decisions based on tourism business stakeholders, prediction of tourism objects with the most visits, and knowledge of each DM. The risk in this study is more to the comparison of the two models above, which can affect the level of tourist visits based on decisions from tourism business stakeholders. The application of the Group decision support system model combined with the knowledge base can produce an alternative decision with recommendations to support the development of tourism objects, especially in the Bali area.

The initial stages of tourism GDSS modeling design using risk analysis based knowledge-based are described below. The risk analysis model is the integration of results after comparing alternative decisions, risk analysis, and knowledge base. It can provide advice and solutions to the problems found in each tourist attraction.

- Stage 1: Preparing preliminary data, namely alternative tourism data, tourism criteria data, assessment data of each Decision Maker (DM).
- stage 2: Determining the criteria weight of each DM using the AHP method, and an alternative assessment of attractions by each DM.

- Stage 3: Determining individual decision alternative of each DM using the AHP method, and determining alternative group decisions, visit tourist attractions using BORDA method.
- Stage 4: Applying Risk Analysis Approach, Knowledgebase about the condition of attractions related to the interests of DM, and parameters about the condition of tourism object.
- Stage 5: Risks of tourism business, Knowledge Representation, Knowledge Acquisition, Decision Tree Decision table, Production Principles, Tourism Business Risk Analysis.

A. *Design of the Proposed Model*

Fig. 1 shows the architecture of system design that will be developed. There are two main processes in implementing the system, namely alternative group decisions using GDSS and Knowledge-based risk analysis. This modeling aims to determine alternative decisions for tourism objects according to tourism business stakeholders. An alternative process for the decision of the tourism object group uses the GDSS method approach. This method begins with an alternative process of individual decisions of each decision-maker using the AHP method. Thus, the results are obtained by individual alternative decisions [34], In each tourism stakeholder. There are ten individual decision-makers (DM) assessing each alternative tourism object, which is shown in Table I. The decision makes Tourist DM, Government DM, Business DM, Academic DM, and Community DM. After obtaining the alternative results of individual decisions, an alternative decision in groups is conducted using the BORDA method [17], [35], in that method, alternative with top-ranking positions are given higher values with candidates in the next ranking position in a pairwise comparison. The alternatives consist of 10 attractions, and each tourism object's selection is based on the highest visit during the last ten years. DM has specific criteria, varying from one another. Their preferences for each tourist attraction are different as well. GDSS model obtains an alternative group decision.

GDSS in this research is a group decision support system that supports and provides several decision alternatives from several experts in tourism. Tourism data obtained from several sources such as the Office of Tourism, Central Statistics Agency, questionnaire data, and interviews from each expert are then processed using the AHP method. The initial process is determining the criteria weight for each alternative tourist attraction, and the assessment is carried out by each decision holder (DM) [36]–[38], by having different criteria from one another. Each DM then gives preference to the given criteria [39], DM with different expertise gives different preferences according to their level of interest.

B. *Research Data*

Data on alternative group decision calculation is obtained from several experts called decision maker (DM). Each DM has different preferences for each tourist attraction. More detailed, each DM is described in Table I. In Table I, several decision-makers have Sub-DM, such as tourist DM consisting of domestic and foreign tourists, community DM consisting of indigenous peoples and officers, and entrepreneur DM consisting of associations of lodging entrepreneurs, restaurants, travel agents, and souvenir sellers.

Knowledge is derived from each DM, which is listed in Table I. Compiling the knowledge base requires knowledge representation. Knowledge representation is composed of two essential elements, namely facts and rules. Facts are information about objects in a particular problem area, while rules are information about how to get new facts from known facts [20].

The alternative tourist attraction in this study is shown in Table II. There are ten alternative tourist attractions obtained from the most number of tourist visits during the last ten years (2008-2017). Each DM has different preferences to the criteria of each tourist attraction because each DM has a different view according to the expertise and authority possessed by DM. The tourism criteria is show in Table III.

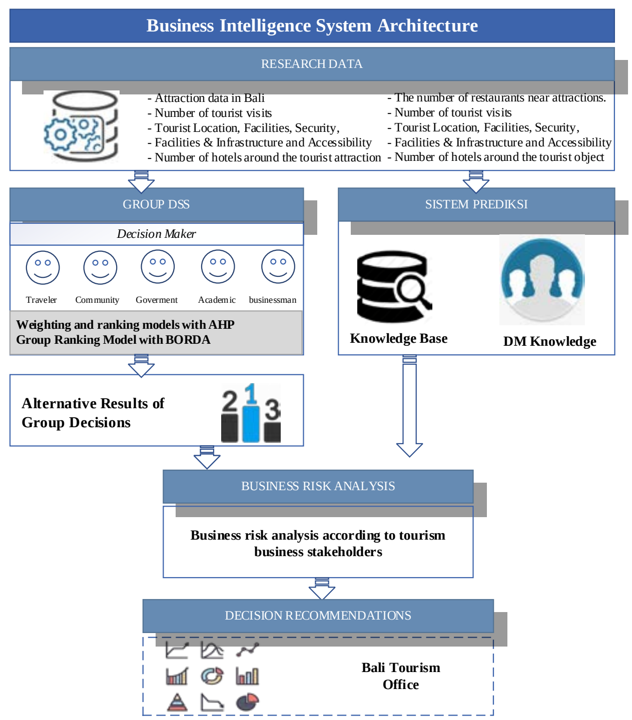

Fig. 1. Business Intelligence System Architecture Model.

TABLE I. DECISION MAKER AND KNOWLEDGE BASE

Decision Maker	***Sub-DM***	***Kode***
Traveler	Foreign tourists	DM$_1$
Traveler	Domestic tourists	DM$_2$
Government	Bali Tourism Office	DM$_3$
Community	Public culture	DM$_4$
Community	Community Service	DM$_5$
Academics	Academics	DM$_6$
Businessman	Hotel Association	DM$_7$
Businessman	Restaurant Association	DM$_8$
Businessman	Travel Agent Association	DM$_9$
Businessman	Cindramata Sales Association	DM$_{10}$

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TABLE II. ALTERNATIVE TOURISM OBJECTS

No.	*Alternative Tourism Objects*	*Code*
1	Tanah Lot	A_1
2	Kebun Raya Bedugul	A_2
3	Pura Uluwatu	A_3
4	Penelokan Batur	A_4
5	Ulun Danu Beratan	A_5
6	Tirta Empul	A_6
7	Taman Ayun	A_7
8	Sangeh	A_8
9	Kawasan Nusa Dua	A_9
10	Goa Gajah	A_{10}

TABLE III. TOURISM CRITERIA

Code	*Tourist Criteria*	*Character*
C_1	Motorized Vehicle Parking	Objective
C_2	Bathroom or Toilet	Objective
C_3	Medical facility	Objective
C_4	information Center	Objective
C_5	Security Posts / Safety Oversight	Objective
C_6	Cindramata Shopping Place	Objective
C_7	There Are Hotels Around Attractions	Objective
C_8	There are restaurants or restaurants	Objective
C_9	Object Promotion & Objective Promotion	Objective
C_{10}	Cleanliness	Objective
C_{11}	Natural Disasters and Crime Levels	Objective
C_{12}	Children's Playground	Objective
C_{13}	Worship place	Objective
C_{14}	Online Assessment	Subjective
C_{15}	Natural tourist attraction	Subjective
C_{16}	Opening a Business Field	Objective
C_{17}	PAD Tourism objects enter the Regional Distinctive	Objective
C_{18}	There are Performing Arts and Culture	Objective
C_{19}	There is a socialization and education on the improvement of tourism objects	Subjective
…	…	…
C_{142}	Local products traded	Objective

Each DM has several criteria, as shown in Table III. A detailed description of the criteria of each decision-maker is shown in Table IV. Table IV shows that tourist DM has criteria for motorized vehicle parking, toilets, health facilities, and others. Government DM has PAD criteria for tourism objects, vehicle parking, government socialization, and others. The criteria consist of objective or subjective factors. Most of the criteria on these attractions are objective, adjusted for each tourist attraction.

The knowledge base in this study uses the concept of decision support in the form of a group (Group Decision Support System).

TABLE IV. CRITERIA FOR EACH DM

Kode DM	*Kode Kriteria*
DM_1	C_1, C_2, C_3, C_4, C_5, C_6,C_7, C_8,C_9, C_{10}, C_{11}, C_{12},C_{13},C_{14}, C_{15}, C_{16}, C_{17}, C_{18}, C_{19}, C_{20}, C_{21}, C_{22}, C_{23}, C_{24}, C_{25}, C_{26}, C_{27}, C_{28}, C_{29}, C_{30}, C_{31}, C_{32}, C_{33}, C_{34}, C_{35}, C_{36}, C_{37}, C_{38}, C_{39}, C_{40}, C_{41}, C_{42}, C_{43}, C_{44}, C_{45}, C_{46}
DM_2	C_1, C_2, C_3, C_4, C_5, C_6,C_7, C_8,C_9, C_{10}, C_{11}, C_{12},C_{13},C_{14}, C_{15}, C_{16}, C_{17}, C_{18}, C_{19}, C_{20}, C_{21}, C_{22}, C_{23}, C_{24}, C_{25}, C_{26}, C_{27}, C_{28}, C_{29}, C_{30}, C_{31}, C_{32}, C_{33}, C_{34}, C_{35}, C_{36}, C_{37}, C_{38}, C_{39}, C_{40}, C_{41}, C_{42}, C_{43}, C_{44}, C_{45}, C_{46}
DM_3	C_{47}, C_{48}, C_{49}, C_{50}, C_{51}, C_{52}, C_{53}, C_{54},C_{55}, C_{56}, C_{57}, C_{58}, C_{59}, C_{60}, C_{61}
DM_4	C_{60}, C_{61}, C_{62}, C_{63}, C_{64}, C_{65}, C_{66}, C_{67}, C_{68}, C_{69}, C_{70}, C_{71}, C_{72}, C_{73}, C_{74}
DM_5	C_{60}, C_{68}, C_{62}, C_{63}, C_{64}, C_{65}, C_{66}, C_{67}, C_{68}, C_{69}, C_{70}, C_{71}, C_{72}, C_{73}, C_{74}
DM_6	C_{75}, C_{76}, C_{77}, C_{78}, C_{79}, C_{80}, C_{81}, C_{82}, C_{83}, C_{84}, C_{85}, C_{86}, C_{87}, C_{88}, C_{89}
DM_7	C_{92}, C_{93}, C_{94}, C_{95}, C_{96}, C_{97}, C_{98}, C_{99}, C_{100}, C_{101}, C_{102}, C_{103}, C_{104}, C_{105}, C_{106}
DM_8	C_{107}, C_{108}, C_{109}, C_{110}, C_{111}, C_{112}, C_{113}, C_{114}, C_{115}, C_{116}, C_{117}, C_{118}, C_{119}, C_{120}, C_{121}
DM_9	C_{122}, C_{123}, C_{124}, C_{125}, C_{126}, C_{127}, C_{128}, C_{129}, C_{130}, C_{131}, C_{132}
DM_{10}	C_{133}, C_{134}, C_{135}, C_{136}, C_{137}, C_{138}, C_{139}, C_{140}, C_{141}, C_{142}

Decision supporter (experts) play a role in providing preferences related to the selection of attractions. Experienced experts or decision-makers (DM) have expertise in both the tourism field and tourism business. The decision-maker group is denoted by vector e, where e_k is the decision-maker k, k = 1, 2, 3, ..., K. In this study, a total of five groups of decision-makers participate in giving preferences.

TABLE V. KNOWLEDGE REPRESENTATION

Description of Knowledge Criteria	*Code*	*Criteria*
The parking attendant or guard cannot speak foreign languages	S001	C_1
There are no parking guards or pecalang	S002	C_1
Around the tourist attraction there is no money changer	S003	C_1
There are parking guards or pecalang	S004	C_1
There are no foreign language signs or instructions	S005	C_1
Parking attendants or guards are able to speak English	S006	C_1
There are signs or foreign language instructions	S007	C_1
Around the tourist attraction there is a money changer	S008	C_1
Parking fees exceed goverment rules	S009	C_1
Lack of supervision and no cctv	S010	C_1
…	…	…
Local products are done by the local community	S109	C_{92}

The criteria are in the form of conditions and facilities in each tourist attraction. The feature is then denoted by a, where ai is the feature i, i = 1, 2, 3, ..., m. Table V shows the knowledge representation of tourism criteria.

C. Determining Alternative Group Decisions using AHP and BORDA Methods

The stages carried out in the process of selecting alternative tourist attractions in groups are done through several stages using AHP and BORDA models as follows:

- Stage 1: Determining the weight of each criterion using AHP model [40], [41], by previously making a pairwise comparison matrix.
- Stage 2: Calculating the value of each alternative to obtain an alternative decision using AHP method.
- Stage 3: Carrying out an aggregation of the preferences given by the decision-makers using BORDA method, and alternative solutions are known in groups in determining tourism objects according to each decision maker's choice [11], [42], the method without calculating the weight of each stakeholder.

Determination of the weight of each criterion with the AHP model, in Phase 1 is carried out with several stages as follows, which include [16] while the determination of individual alternatives uses the same calculation by comparing each alternative :

1) Form a hierarchical structure between criteria and alternatives, with an assessment using an approach on the scale of comparative values [41], [43], there are a maximum of 15 criteria in the calculation.

2) Creating a comparison matrix, The comparison matrix is a square matrix A= $(a_{ij})_{nxn}$ which covers: $a_{ij} > 0$, $a_{ij} = 1/a_{ji}$ dan $a_{ii} = a_{jj} = 1$, often called the reciprocal matrix. The comparison matrix uses a comparison value scale 1-9.

3) Calculates the multiplication result of each element in each row *Mi*, according to the equation (1).

$$Mi = \prod_{j=1}^{n} a_{ij} \quad (1)$$

4) Calculates n square root of *Mi* using equations (2).

$$\lambda \max = \sum_{i=1}^{n} \quad \sum_{j}^{n} a_{ij} W_j \,, \overline{Wi} = \sqrt[n]{Mi} \quad (2)$$

5) Number of *vector* $Wi = (\overline{W1}, \overline{W2}, \dots, \overline{Wn})^t$, for the normalization process can be seen in the equation (3).

$$Wi = \frac{\overline{W_i}}{\sum_{j=1}^{n} \overline{W_i}} \quad (3)$$

6) Consistency test, the process of calculating the consistency index (CI) can be seen in the equation (4).

$$\text{CI} = \frac{(\lambda \text{ maks} - \text{n})}{(\text{n} - 1)}, \lambda \max = \sum_{i=1}^{n} \quad \sum_{j}^{n} a_{ij} W_j \quad (4)$$

7) Calculating the consistency ratio (CR) can be seen in the equation (5).

$$\text{CR} = \frac{\text{CI}}{\text{RI}} \quad (5)$$

The value of a random consistency index (RI) is shown in the research.

Alternative decisions are determined individually using AHP method approach to obtain an alternative decision for each individual. Calculations using AHP method are done using calculations in the first stage, but the thing to be compared is an alternative tourist attraction for each criterion.

The problem that often arises in GDSS is how to aggregate the opinion of decision-makers to gain an appropriate decision [44]–[46], so that decision making can produce policies for the development of tourism in Bali. One of the group decision methods is Borda, which is a voting method that can resolve group decision making, where each decision-maker gives a rating based on alternative options available [47]–[49], with the first alternative getting the highest value and the last alternative getting the lowest value, one. The implementation of the BORDA method is described in Table VI [48], the highest value is the first alternative decision.

Alternative that has the highest value is a material consideration to be chosen [48]. The calculation result of the Borda method involves alternative point value A, namely (3 + 2 + 4) = 9, alternative B (4 + 4 + 3) = 11, alternative C (1 + 1 + 2) = 4, and alternative D (2+ 3 + 1) = 6. Based on the calculation of Borda method above, it can be concluded that the highest point value is alternative B.

D. Design of Knowledge Representation

Knowledge representation aims to create a structure that will be used to help to encode knowledge into the program, which is used to support problem-solving [50]–[52]. This knowledge model aims at assisting users in making decisions from the risk analysis of tourist attraction selection [53]–[55]. The knowledge obtained is from several experts or decision-makers shown in Table I. In this study, five groups of decision-makers participating in giving preferences. The features are the conditions and facilities found in each tourism object. The feature is then denoted by a, where a_i is the feature i, i = 1,2,3, ..., m.

Knowledge processing is gained from knowledge acquisition, so it comes to the form of production rules consisting of several stages, namely:

a) Making decision tree: Decision tree represents knowledge described in the form of a systematic design until the conclusions are reached. The decision tree for tourism object selection is shown in Fig. 2.

TABLE VI. EXAMPLE OF BORDA CALCULATION

***Decision-Maker* (DM)**	**Alternative choices**				**Ranking**	**Points**
	A	**B**	**C**	**D**		
DM 1	2	1	4	3	1	4
DM 2	3	1	4	2	2	3
DM 3	1	2	3	4	3	2
Calculation of the Borda Method	9	11	4	6	4	1

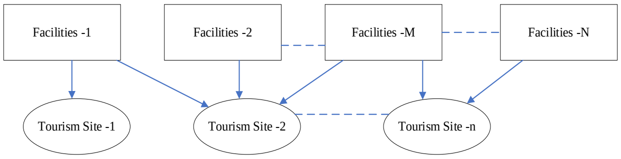

Fig. 2. The Relationship between Features / Criteria and Attractions.

b) Making decision tables: Decision tables represent knowledge in the form of rows and columns. The first part is a list of attributes of each listed attribute, and the next one is the conclusion of each attribute.

c) Compiling the rules of production: The rules of production are knowledge represented in the form of conditions - action pairs, IF condition (premise or antecedent) occurs, THEN actions (conclusion). The rules of production are arranged based on the decision tree and decision table, as in Table VII.

TABLE VII. PRODUCTION RULES

Rule 1
IF Distance from the airport is less than 50 Km
AND management management by the private sector
AND There is a Guard post
AND Distance from the nearest police station 5 Km
AND there are hotel villas and art shops
THEN
Uluwatu Temple Tourism Object
Rule 2
IF There are educational facilities
AND management management by the private sector
AND There is a checkpoint
THEN
Ulun Danu Tourism Object

E. Determining Types of Risk Analysis

In this study, the focus of risk analysis is more on the impact of the risks of tourist attractions and tourist visits. Risk analysis is determining based on alternative group decisions of tourist visits based on tourism business stakeholders, prediction of attractions with the most visits, and knowledge of each DM. The flowchart of risk analysis is described in Fig. 3.

The risks in this study focus more on the results of comparing the two models above, which can affect the level of tourist visits based on the decisions of tourism business stakeholders. If the results of the risk analysis of BI system do not match the results of alternative group decisions with the predicted results of tourist visits, it is not appropriate. The results can be said to be appropriate if GDSS results in the form of alternative group decisions are following the decision-makers or DMs estimate a high number of tourist visits when compared to other attractions. If the selected tourism objects have a low level of visits, then the problem will enter the settlement following these conditions.

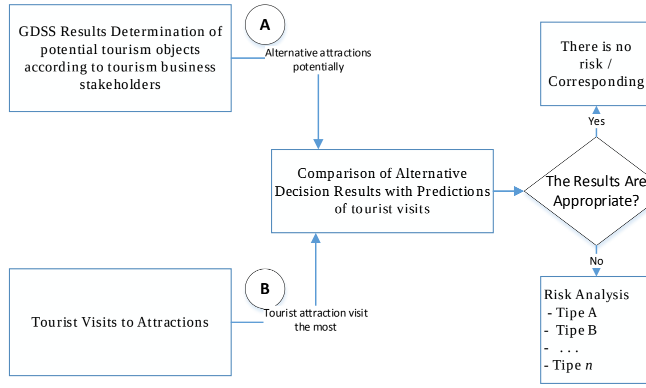

Fig. 3. The Design of Risk Analysis on Alternative Attractions.

Several types may arise from the results of risk analysis, including:

- Type 1 : The value of (A) alternatif decision **a** is greater than value of **b**, but the prediction (B) in **a** is smaller then **b**
- Type 2: The value of (A) alternatif decision **a** is smaller than value of **b**, but the prediction (B) in **a** is greater than **b**
- Type 3: The value of (A) alternatif decision **a** is less 2 step than value of **b**, but the predicion (B) of **b** is far greater
- Type 4: The value of (A) alternatif decision **a** is less than 1 rank with value of **b**, but the prediction (B) of **a** is much smaller.
- Type 5: The value of (A) alternatif decision **a** is more than 1 rank with value of **b** , but the prediction (B) of **a** is far greater than **b**

Explanation, tourism object to be compared symbolized by **a** and comparative tourism object are symbolized by **b.**

Risks are used to show the consequences, not only negative but also positive consequences. The occurrence of risks can affect a strategy or purpose of tourism development in the future. Input to the Provincial Tourism Office of Bali is in the form of risks and solutions to the development of tourism objects according to the results of GDSS model in the form of alternative group decisions. Several types of risk analysis result gain solutions and risks that come from the knowledge of tourism business stakeholders or DM.

The elaboration in Fig. 4 shows the comparative values that obtain knowledge from each DM that is used to improve and to develop tourism objects in the future. Flowchart's comparison of the values of the criteria of alternative decisions is described in Fig. 4. The two values will then produce new knowledge that comes from the value after comparing the best results with the results.

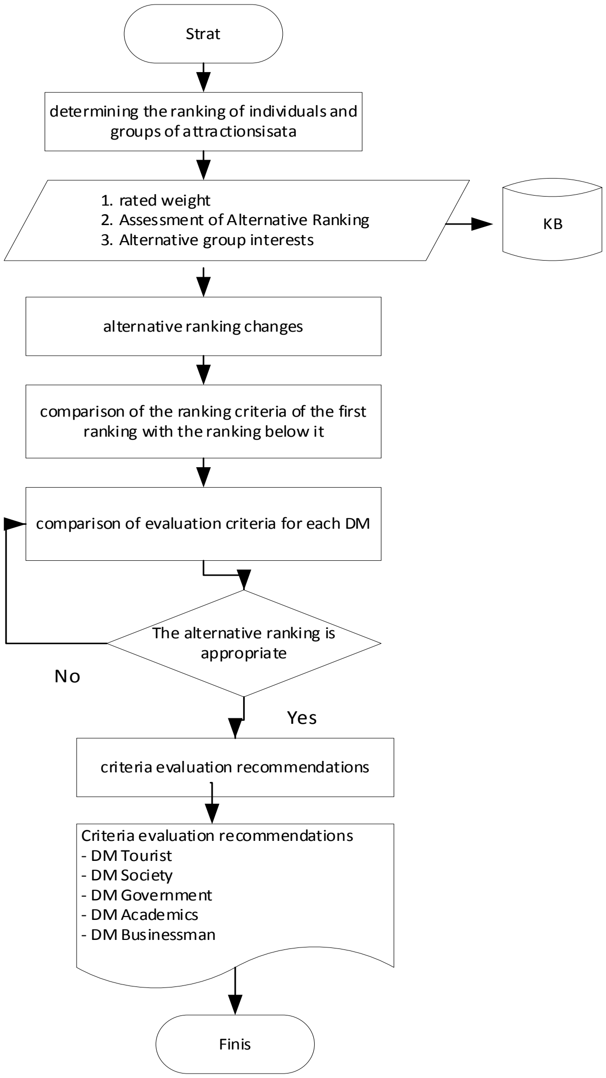

Fig. 4. Flowcharts Determine the Value of Risk Analysis.

IV. Results and Discussion

GDSS Modeling results using knowledge-based risk analysis generate alternative group decisions and input in the form of solutions and risks for tourist attraction development. The purpose of combining these results is to understand the impacts or risks that may arise and recommendations so that a solution can be determined from the knowledge base described previously.

A. Alternative Decision of Individual and Group

The calculation of criteria weight using AHP is done by calculating the weight of parameters that will be used in selecting the best tourist attractions. The process of calculating sub-Criteria facilities and the results of determining the weight uses the AHP model. The results of calculation of sub-criteria weight and tourist criteria are shown in Table VIII.

$$\sum_{i=1}^{12} \overline{w}_i = 3{,}58 + 0{,}37 + 2{,}84 + 0{,}93 + 0{,}44 + 0{,}62 + 1{,}69 + 0{,}44 + 1{,}68 + 1{,}81 + 0{,}61 + 0{,}73 = 15{,}769$$

$$w_1 = \frac{3{,}58}{15{,}769} = 0{,}227$$

λ *max* =(0,23 x 3,96) + (0,024 x 40) + (0,18 x 6,252) + (0,058 x 20) + (0,029 x 36) + (0,039 x 25,5) + (0,107 x 12,1) + (0,028 x 34) + (0,107 x 9,53) + (0,115 x 10,93) + (0,038 x 27,83) + (0,046 x 20,5) = 12,73

$$CI = \frac{12{,}73 - 12}{12 - 1} = 0.0665, CR = \frac{0{,}0665}{1{,}48} = 0.04495$$

The consistency ratio value of 0.44956 is considered consistent because it is lower than 0.1. The results of calculation is obtained using BORDA model, and the results obtaining ranking individual alternatives are shown in Table IX.

TABLE VIII. Weight for Facility Criteria on DM Tourists

Code	DM Foreign tourists			DM Domestic tourists		
	Sub-Criteria Weight	Criteria Weight	Global Criteria Weight	Sub-Criteria Weight	Criteria Weight	Global Criteria Weight
C_1		0,2271	0,0104		0,2221	0,0256
C_2		0,0237	0,0011		0,0464	0,0053
C_3		0,1801	0,0082		0,1385	0,0159
C_4		0,0588	0,0027		0,0586	0,0067
C_5		0,0285	0,0013		0,0386	0,0044
C_6	0,045	0,0390	0,0018	0,1151	0,0513	0,0059
C_7		0,1075	0,0049		0,1000	0,0115
C_8		0,0279	0,0013		0,0344	0,0040
C_9		0,1071	0,0049		0,1085	0,0125
C_{10}		0,1150	0,0053		0,1070	0,0123
C_{11}		0,0387	0,0018		0,0452	0,0052
C_{12}		0,0466	0,0021		0,0495	0,0057

TABLE IX. Alternative Outcomes of Group Decisions

Code	*Alternative Tourism Objects*	*Total Value*	*Alternative*
A_1	Tanah Lot	96	1
A_2	Kebun Raya Bedugul	82	3
A_3	Pura Uluwatu	84	2
A_4	Penelokan Batur	30	8
A_5	Ulun Danu Beratan	50	6
A_6	Tirta Empul	60	5
A_7	Taman Ayun	40	7
A_8	Sangeh	22	9
A_9	Kawasan Nusa Dua	71	4
A_{10}	Goa Gajah	16	10

Tanah Lot tourism object with point 96 becomes the choice of all DMs, while Goa Gajah tourism object becomes the last choice, obtaining point 16. Determination of the point of each alternative is based on the ranking of the previous individual alternatives.

B. *Representation of Knowledge of each DM*

The knowledge generated by each DM is then represented into the knowledge base so that solutions and risks can be determined by comparing alternative attractions.

In general, knowledge representation elaborates on the criteria in Table III, such as parking vehicles, toilets, health facilities, and so on. The specific representation of knowledge for motor vehicle parking criteria is elaborated in Table X. Each criterion has several different rules adjusted for DM assessment.

In Table X, describing the production method for the criteria for motorized parking, knowledge is represented in terms of condition-action pairs, IF conditions (premise or antecedent) occur THEN actions (conclusions or conclusions). The description of the production method refers to the criteria listed in Table III. The assessment for each criterion is carried out by each DM, with different representations of knowledge from each other.

TABLE X. THE METHOD OF PRODUCING TOURIST KNOWLEDGE

Rule 1
IF Parking Levies exceed PEMDA rules
AND There are no parking guards / pecalang
AND Lack of supervision and no CCTV
AND There is no helmet storage
AND Outside of vehicle parking is less than 500 m2
AND There is no guarantee of vehicle safety
THEN
Parking ticket fees are expensive
AND The parking lot is narrow
AND Parking lot security is not guaranteed
AND Helmets are prone to disappear
Rule 2
IF Parking Levies exceed PEMDA rules
AND Lack of supervision and no CCTV
AND Location Parking away from attractions
AND There is no helmet storage
AND Outside parking of vehicles between 500 m2 and 1000 m2
THEN
Expensive parking ticket levies
AND tourists walk far to the tourist attraction
AND Parking lot security is not guaranteed
AND Helmets are prone to disappear

C. *Risk Analysis Results*

The result of the comparison of Tanah Lot with Goa Gajah. Tanah Lot tourism object becomes the benchmark in comparison value, Tanah Lot becomes the benchmark because it is a group choice from the alternative selection of tourism object decisions that are following the interests.

Comparative tourism objects are symbolized by the letter B. Each of the criterion values owned by the two attractions in detail is compared to the results one by one. It can be known for differences in values that refer to KB-based risk analysis. For example parking criteria, the Tanah Lot tourism object has a criterion value of 4 while for Goa Lawah tourism the criterion value is 1, as shown in Table XI.

TABLE XI. RISK ANALYSIS AND TOURISM SOLUTION FOR MOTORIZED VEHICLE PARKING

DM_1
Risk / Impact
Foreign tourists are demanding, communicating with parking attendants, Foreign tourists find it difficult to understand the conditions in the parking lot, Parking lot security is not guaranteed. It is hard to do a transaction if not have rupiah.
Solution / Suggestion
Parking attendants or guards can speak foreign languages ,There are parking guards or pecalang, There are signs or foreign language instructions, Around the tourist attraction, there is a money changer service
DM_2
Risk / Impact
Expensive parking ticket levies, Narrow parking lot, Parking lot security is not guaranteed. Helmets are prone to disappear. Parking space is not conducive and without shade.
Solution / Suggestion
Free vehicle parking, There are parking guards or pecalang in the parking area, Close supervision and no CCTV, vehicle security is guaranteed, Location Parking is conducive and not far from attractions Helmet custody is available
DM_3
Risk / Impact
Can barely accommodate visitors using 4-wheeled vehicles, Can barely accommodate visitors who use large buses, Parking lot security is not guaranteed, Small parking revenue levies.
Solution / Suggestion
Outdoor parking of vehicles more than 2000 m2, There are parking guards or more pecalang, Close supervision and CCTV, Able to accommodate BUS parking, Parking fees do not exceed government regulations, There is a guarantee of vehicle safety, Parking location is a bit far from the tourist attraction
DM_4
Risk / Impact
Local people are not involved in parking management, Many visitors park their vehicles outside the tourist attraction, and parking space security is not guaranteed, The community opened the parking bag, around the tourist attraction, There are illegal levies to tourist attractions.
Solution / Suggestion
The community fully manages parking management, There are parking guards or pecalang, Close supervision and no CCTV Parking fees are according to PEMDA rules

In Table XI, is described one of the criteria, namely, the criteria for motor vehicle parking. Criteria evaluation was carried out by four DMs, namely foreign tourists, domestic tourists, the government, and indigenous peoples. The next comparison results will be obtained knowledge in the form of solutions or recommendations given by the four DMs. The analysis of business risk in this study is included in type 1, with the difference between each tourism object based on alternative group decisions.

V. Conclusion and Future Work

Alternative group decisions using GDSS method, in which there are AHP and BORDA methods, are successfully implemented. This modeling aims to choose attractions that accommodate the preferences of all DM. The results of alternative group decisions conclude Tanah Lot tourism objects as the first choice tourist attraction and Goa Gajah as the last choice.

Risk analysis modeling of Bali tourism business gives recommendations/solutions and risks that will occur based on DM assessment. After comparing parking locations on Tanah Lot and Goa Gajah, there are some solutions, namely, there are Officers who can speak foreign languages, there are parking guards, there are signs or foreign language instructions, and there is a money changer around the attraction. Some of these solutions are recommendations from Foreign Tourist DM, while for other DM have different solutions according to the preferences of each DM. The role of preferences for risk analysis is to accommodate each DM's interests and become known for the tourist attraction development by the expertise of each DM.

GDSS tourism modeling that applies knowledge-based risk analysis as a whole obtains alternative group decisions, which are tourism objects that are in accordance with the interests of each DM. The model can also determine solutions or recommendations and risks based on the comparison of alternative tourism objects. GDSS modeling results in an alternative group decision in the form of Tanah Lot tourism object as the first choice, and Goa Gajah tourism object as the last choice. Thus, Tanah Lot Tourism Object becomes a reference for comparison. Risks that arise based on the comparison with Goa Gajah tourism object, one of which is parking criteria. It will have an impact on the area of vehicle parking. The solution is to expand the area of vehicle parking so that it can accommodate a large number of visitors.

The outline and contribution of this research are to develop a business risk analysis model for alternative decision for the business interests of each stakeholder. The model can provide recommendations or solutions and risks for the alternative development of attractions to Bali's provincial government. The next contribution is the development of a knowledge base model from stakeholders interested in the tourism business in Bali.

The limitation of this model is that it can only be used for the Bali region, because for other areas the development of the model must be done by adjusting the criteria and stakeholders of the region and in accordance with the needs and problems faced, by paying attention to aspects of government regulations, especially the Tourism Office of each area.

One of the issues which is interesting for future work is the model produced in this research can be developed using more than two components in BI system. Other components that can be used are tourist classification and Big Data management so that they can manage large data. OLTP components can also be used so that transactions can run in real-time.

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A Hybrid Document Features Extraction with Clustering based Classification Framework on Large Document Sets

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***Abstract*—As the size of the document collections are increasing day-by-day, finding an essential document clusters for classification problem is one of the major problem due to high inter and intra document variations. Also, most of the conventional classification models such as SVM, neural network and Bayesian models have high true negative rate and error rate for document classification process. In order to improve the computational efficacy of the traditional document classification models, a hybrid feature extraction-based document cluster approach and classification approaches are developed on the large document sets. In the proposed work, a hybrid glove feature selection model is proposed to improve the contextual similarity of the keywords in the large document corpus. In this work, a hybrid document clustering similarity index is optimized to find the essential key document clusters based on the contextual keywords. Finally, a hybrid document classification model is used to classify the clustered documents on large corpus. Experimental results are conducted on different datasets, it is noted that the proposed document clustering-based classification model has high true positive rate, accuracy and low error rate than the conventional models.**

***Keywords*—Classification; document feature extraction; document similarity**

I. Introduction

Machine learning algorithm currently finds wide-spread use in the principles of data mining, where text classification is also a part of it. Work is currently being conducted on the use of machine learning methods to improve efficiency and raising the complexity of computations. Literature in [1] is reviewed about the approaches to machine learning in text classification. The benefit of the suggested solution was that it factored both local and global characteristics, and had the potential to be noise resistant. The suggested solution was shown to work better than traditional SVM methodology, using comparative studies on different datasets. Document representation in vector model is also an essential part in the document clustering algorithms. Several text representations models such as a n-gram models, bag-of-words and feature filtering, etc., have been widely used for large collection of documents. Generally distributed documents share some common context for clustering and categorization [2]. These contexts are represented using documents key terms. Textual data are represented using words and phrases as features in a high dimensional vector space.

Document clustering is the collection of a large number of documents into a set of useful cluster sets where each cluster represents a specific topic or context. The documents within the group should have a high degree of similarity while the degree of similarity among distinct document clusters should be reduced. Traditional clustering methods used to cluster the documents without paying much attention to the contextual information of the document set. For example, if two or more documents are representing same topic using different terminology which are semantically same, the documents are bagged under different clusters. This kind of clustering may lead to inefficient information retrieval. So, document clustering has become an increasingly important for improving the documents sharing and communication in distributed environment. Document clustering has many applications in the area of information retrieval and data mining [3]. For this purpose, different document clustering techniques emerged to better perform the clustering so as to overcome the limitations that are there in the traditional ones.

Clustering methods can be categorized into two main categories. They are Generative approaches (model based) and Discriminative approaches (similarity based). Model based techniques are used to develop extended models from the peer document sets, with each model randomly assigning one particular document cluster. In the similarity based approach [4], function involving pairwise document similarities can be optimized and aiming to optimize the average cluster similarities within the peer overlay clusters.

Moreover, the different levels of analysis are not disjunct. For instance, semantics plays an important role in the syntactic analysis. NLP is a subfield of artificial intelligence and linguistics. In IR, NLP is often used as a pre-processing step. When a system wants to find the most important information in text and then wants to retrieve the information found, it first has to define the most important parts. It is important to note that text mining, IR and NLP are different fields. Sophisticated NLP techniques are frequently used in IR to represent the content of text in an exact way (e.g. noun and verb phrases being the most important ones), extracting the main points of interest, depending on the domain of the IR service. However, NLP is not only used in parsing the documents, but also for handling the user queries. The important information has to be parsed from the user queries in a similar way [5]. NLP techniques are used in almost every aspect of the text mining process, namely in Named Entity Recognition.

The remainder of the paper is described as follows. Section 2 presents detailed information about related work and advances in the field. The proposed hybrid clustering based classification is presented in Section 3. Experimental results are elaborated in Section 4. At the end, conclusion of the paper is detailed in Section 5.

II. Related Works

Two model architectures are available for representing the text in its vector form. The first predicts the current word from the related terms in the immediate surrounding area while ignoring the order of terms and the second predicts with the aid of the current word the surrounding background words. CBOW is quicker to train when skipping – gram is slower, but better in terms of word weight for Word2Vec. Vectors in Google's Word2Vec are trained from Google News documents on 100 billion words, and are open to all publicly. Such vectors have 300 dimensions and are trained using a continuous bag – of – word model, meaning terms. WordNet is a broad database of English-speaking lexical terms [6]. Here the terms connected with each other are grouped into a collection known as Synset. Lexical categories such as nouns, verbs, adjectives etc. form different synsets and are related through conceptual-semantic relationships and lexical relationships. It is a kind of dictionary and thesaurus which can provide meanings to the terms and comparisons with other terms. Words are thus like nodes, and the connections reflect the relations between them. Word types found in various synsets are of different meanings. WordNet's new online edition is 3.1. Similar to WordNet, ConceptNet is also a broad semantic network composed of the principles relevant to our everyday lives. The ideas apply to the principles of commonsense, and this information is derived from the experiences of average people over the Internet. It is the largest shared information base accessible to the public, consisting of over 2,50,000 relationships. These approaches are generally implemented using domain independent approach in order to result better optimization solutions. Different evolutionary approaches such as genetic algorithms, Rough-set, SVM, etc. are used to classify the document sets from large corpus. Genetic algorithms are implemented to find the complex patterns and classification rules on huge datasets [7]. In some of the hybrid approaches, genetic algorithms are integrated with decision tree schemes to generate an optimized decision tree. Classification models such as Naïve bayes with ensemble decision tree models namely CART, C4.5, Bayesian tree and random forest are used to classify document and feature extraction. They concluded that no single traditional model existed to handle uncertainty for document prediction with large number of attributes set. Hadoop is a software framework used for efficient scalable and parallel programming applications in java and is responsible for processing huge amount of data. It operates on distributed environment with specific clusters, provides results with fault tolerant. It can integrate multiple cluster node’s computation and storage data in an efficient manner. Traditional document clustering algorithms are compared in distributed biomedical repositories for efficient document feature extraction [8]. An advanced three-layer biomedical framework has been implemented to cluster the set of documents [9]. This framework is based on a multi-layer neural structure of neighborhood peers. Many overlay peers which act as the representative object of its lower neighborhoods are clustered to form higher level clusters. The basic limitation of this model is selecting an optimal threshold for a dynamic size overlay network. Also, it is very hard to balance the structure size and peer documents.

A model using a parallel approach is implemented to cluster the multiple document collections [10]. The key issue is to find automatic document clusters in large text corpus and it is very high cost to compare documents in a high dimensional vector space. This algorithm tries to minimize the distance computations and cluster size in the training dataset documents, called pivots. They used parallel algorithm in an efficient way to optimize a complex data structure which affords efficient indexing, searching and sorting. Traditional probability estimation techniques such as Naïve bayes, markov model, Bayesian model [11] are used to find the highest probability estimation variance among the gene and its related disease sets in biomedical document sets. Classification is the process of finding and extracting the main contextual meaning of the gene or disease patterns from the distributed document sources and it has become an integral part of day to day activities in all domains like cloud, forums, social networking and medical repositories. Automatic text Classification fulfills certain goals by implementing Classification techniques at the user end to find relevant summaries of the large document sets. Document summaries represent sentences or phrases extracted from different sources without any subjective human intervention or editorial touch and thus making the end product completely unbiased. Classification is a highly interdisciplinary field involving areas like information extraction, text mining, and information retrieval, natural language processing and medical databases. Currently, many scholars at home and abroad have studied the technology of text classification using key methods like conventional machine learning and the deep learning that is currently common. They define the "Clustering of full-subtopic retrieval with keyyphrase-based search results," in that Consider the problem of multiple documents related to the individual subtopics of a Web query, called "complete child retrieval". They present a new algorithm for grouping search results to solve this problem which generates clusters labeled with key phrases [12]. The key phrases are extracted from the search results generic suffix tree and combine into a grouping enhanced by a hierarchical agglomeration process. They also presented a new method to assess the success of complete recovery subthemes, namely "look for secondary duration arguments under adequate documentation". They used a test set explicitly designed to assess the recovery of the subthemes, they found that our algorithm passed all other clustering algorithms of existing research results as a method of redirecting search results underlines the diversity of the results (at least for k>1), that is to say when they are interested in recovering more than one related sub-theme document).

Kostkina et al. [13], they suggested a new approach which expanded the features of short text based Wikipedia and Word2vec. The first phase was the creation of Wikipedia's semantine related definition sets. The semantic relationship between the goal and related concepts was measured; the authors received articles which were highly applicable to the Wikipedia concepts. The author then expanded the applicable notion sets to short texts, and it was noted that this methodology could achieve greater semantine relatedness compared to traditional similarity calculation principles using statistical approach. Experimentally it was shown that the precision of classification could be invented by extending the features of short texts.

Mishra et al. [14], a new system of the Word Embedding Function Extension for Short Text (WEFEST) that extended short texts using word embedding for classification is presented. The proposed WEFEST was embedded in a deep-language model in which word corrections were used to learn a new embedding space. Thanks to the phase the new function vectors space is picked. The use of pre-trained word function embedded in each short text in the training dataset has been enhanced, the authors made use of the nearest neighboring algorithm to achieve short text classification, and the effectiveness of the suggested technique has been validated by the empirical results on Chinese news websites containing title datasets for text classification. They applied the various function extraction methods, feature representation methodology, and text classification approaches. The proposed work was focused on forensic autopsy knowledge to find suitable methods for extraction of features, meaning of features and categorization of texts. From the empirical findings it has been discovered that the unigram features outperformed bigram, trigram, and unigram, bigram, and trigram variants. Compared with normalized TF-IDF structures, the TF and TF-IDF value representation approach works efficiently. LDA was used to extract the thematic details. The authors could add features that were relevant to the subject to the document defined by feature set to enhance the classification of the text. The authors [15] explored various forms of terms frequency and topic-related data, and these were considered traits for supporting vector machine. The experimental results on three companies showed that the accuracy of text classification could be improved by combined features. Unlike the supervised selection technique, which includes category information in the training data, Park et al. [16] proposed an unsupervised feature selection technique in which no information based on categories was needed. This helped the framework to include more framework scenarios, since labeled data was both expensive and not very reliable. Like the other unsupervised methods, this technique made use of embedding terms to identify terms that had virtually the same semantic meaning. The word embedding maps the terms into vectors, preserving the semantine relationships between terms. Many of the words were not used as features to prevent redundancy; the writers chose the most suitable word with similar semantic meaning. Sinoara et al. [17] proposed feature selection technique that was based on Kullback-Leibler (KL) divergence. The purpose of this technique is to evaluate the current association between each class and subclass through KL divergence. The Mutual information method was used for calculating the correlation between each feature and subclass; Term frequency probability was used for measuring the importance of subclass characteristics, so that, for parent class node, a superior discrimination set of features could be selected. The authors used hierarchical feature selection techniques and SVM classifiers on two organizations for purposes of hierarchical text classification tasks. Experiments showed that the proposed algorithm was successful compared to the cchi square statistics (CHI), information gain (IG), and shared knowledge (MI) directly used to pick hierarchical features.

Jiang et al. [18] proposed a novel text classification algorithm, based on the Ant Colony Optimization (ACO). It abused the discreteness of the features of the text document and the value the ACO provides in addressing discrete issues. The behavior of the ant population having the class information was used for classifying the text in order to find a suitable route matching during the process of iterating the algorithm. A score of connectedness between two concepts was high if there were several paths between them (which consisted of direct / indirect hyperlinks). Now TD and WD were concatenated vertically to form the TD&WD matrix, which was used for classification purposes. Of the grouping, they used majority voting methodology. At Reuters (0.9331), 20 Newsgroup (0.7563), and RCV1 (0.5198), their scheme registered appropriate classification accuracies.

Song et al. [19] used NPE for selection of features and applied the PSO classifier for classification of documents. NPE is a better feature-selection scheme than Latent Semantic Indexing, they stated. LSI has proven to be a powerful tool for various information retrieval tasks but it may not be a successful discriminating feature selector for classifying documents into different categories. Feature extraction is a core concept in the text classification process. To build lexical chains, Ravindran tap semantine tools such as synonyms and identity [20]. Based on lexical chains, a two-pass algorithm generates feature vectors, first generating all possible lexical chains and then selecting the longest chains. Through removing unimportant strings, they achieve a reduction of 30 per cent in function vector dimensions and an increase of 74 per cent in execution time. Apart from English, it is also used in the classification of sentiments in the Chinese language text. Likewise, it was used for recurrent neural networks and the findings outperform the standard techniques in both cases. A further attempt was made to identify document using word2vec in combination with the LDA method [21], which also provided better results. In addition to text classification, word2vec has been used in many other areas of application such as improving medical knowledge through unsupervised medical corporate learning [22], answer selected from possible collection, good, poor in a question – response method [23], etc. Word2Vec is an unsupervised model of writing, writing the semantic context associated with the text. They developed a framework by using Information Retrieval (IR) strategies to extract information in biomedical domain [24]. According to the relevance degree, their framework can rank the documents. Their framework can extract relevant documents as well as can diversify the information. The authors presented two labelling methods and merged some IR models. They validated their theory by experimenting on TREC Genomics datasets and result enhanced performance.

Ma et al. [25] presented an algorithm for biomedical documents classification by using Medical Subject Headings (MeSH) and MEDLINE indexing. The author considered 50 articles from MEDLINE and classified these documents by the above said algorithm which uses Natural Language Processing scheme. After calculating precision and recall manually for individual documents, he calculated average precision and recall. The author also identified three major flaws for this approach. Those are: 1) Precision and recall are decreased significantly because of the exact matching. 2) The given algorithm is unable to classify an abstract of biomedical documents. 3) Because blogs terminologies are not MeSH headings, the algorithm can't be applied to the articles of blogs. To overcome these flaws, future research and work is necessary for this method. Park et al. [26] proposed an algorithm that results the top search results for IR queries. For their approach Boolean interface is used without ranking functions. Through conjunction of queries ranked documents are resulted using relevance metric. By the efficient use of probabilistic modelling, the researchers formed their algorithm. The above algorithm sets off a minimum cut-off for the documents to be categorized under high ranking. They argued that, their technique supports monotonic ranking of various keywords and the respective interface uses Boolean expression of keywords. The authors validated their methodology by experimenting on PubMed database and TREC dataset and got enhanced results.

Rashid et al. [27], introduced two new deep learning approaches. They calculated the embedded words and analyzed that with other modelling approaches. As compared to other deep learning approaches of biomedical documents mining, the above said algorithm results better performance. They categorized their research into three sub-categories: 1) Various domain-specific representation are analyzed and a new word embedding approach is proposed. 2) DBN-base DDIE model and RNN-based NER model are introduced through which the process of word embedding is done, and it is compared with skip-gram, CBOW, GolVe, etc. 3) This technique shows significant results in word embedding with better recall. Extraction of keywords from text data is an important technique used by search engines and indexing services to quickly categorize and locate relevant data based on keywords explicitly or implicitly provided. In this section, the literature review involves the various methods used to locate and identify keywords in the individual papers, social networking sites, lecture audio archives, speech transcripts, website database etc. It is important to note that most of the algorithms to be considered in the analysis used an external corpus of documents to check and assess the algorithms' performance. Similarly, these algorithms relied on a weighted function that combined some measure of the presence of a word or phrase within a text with a similar measure from the body. The most common measurements used were word frequency, word distance, document position of terms, co-occurrence with other terms, word-to-word relationship (lexical chains), key phrases, etc. They suggested a system for extracting keywords that would work on individual documents. They followed a text-oriented approach in which, irrespective of the current state of a corpus, the same keywords are extracted from a text The DIKpE algorithm was evaluated on a publicly accessible keyyphrase extraction dataset containing 215 full-length documents from various computer science subjects for its effectiveness and performance. DIKpE was evaluated by measuring the number of matches automatically extracted between the key phrases attached to the text and the keyphrases. DIKpE was found to have clearly outperformed the other two algorithms in extracting the keyphrases, although no training activity was undertaken. They discussed many techniques for automated (unsupervised) keyword extraction for voice transcripts. He found the multiparty meeting domain in particular, and explored the suitability of certain algorithms that were successfully used in meeting transcripts for automated keyword extraction of written text. To test these keyword extraction algorithms, they used transcripts from the ICSI meeting corpus. They also integrated POS filtering, word clustering, sentence salience score into the TF-IDF system and evaluated the outcomes. The accuracy and efficiency of the thematic classification were determined. Two unsupervised discriminative terms were used to automatically classify transcriptions which were extremely incomplete. Term Frequency – Inverse Document Frequency (TF-IDF) using the Gini Purity criteria approach was used to identify the transcription themes. They discovered that the Wikipedia page redirects to automatically gain language-independent variations in morphological character. Four languages have been used for research, namely 3.83,000 Arabic documents, 50 million English documents, 50,000 Hungarian documents and 2.11,000 Portuguese documents. For performance measurement, standardized discounted cumulative benefit and mean average precision were used. The authors in [29] performed Arabic stemming responsive material and substantial progress in English retrieval, outperforming words and stems. Classified news articles using the KNN approach to machine learning. Naïve Bayes term graph model, K-nearest Neighbours (KNN), was used by the authors as a hybrid approach to obtain accurate results. The authors used Reuters dataset with 21578 articles, in which 9603 were training papers and 3299 were test papers. Specific pre-processing methods were used to achieve better results for the documents. A model program for the Vector space was developed and relevant documents were collected for the query. The authors clarified the methods used in text classification such as, K-Nearest Neighbors, Regression Models, Decision Trees, Decision Rules, Naïve Bayes and Bayesian Networks. Significant division of news articles based on classifying documents into various categories, the relevant document was displayed when entering keywords. For each document Association Rule Mining algorithm was applied to find the frequently co-occurring terms and then mapped to a weighted and guided graph. Unsupervised approaches typically include assigning each candidate's sentence a saliency score by considering various features. Supervised machine learning algorithms have been proposed to identify a candidate's phrase either into a main phrase or not using features such as occurrence frequency, POS details and position of the term in the text. Both of the above methods make use of the document text only to produce key phrases and cannot (as-is) be used to produce label-specific key phrases.

The keyword extraction model was developed using both statistical as well as pattern features inside words. The algorithm is independent of language and does not require a semantic dictionary to obtain the semantic features [30] suggested an improved extraction method for the keyword (Extended TF). Document clustering by consensus and classification (DCCC) model is implemented in [28] to perform cluster based classification on the limited high dimensional datasets with limited dimensions.

III. A Hybrid Document Clustering based Classification Framework

Fig. 1 describes the proposed cluster-based document classification framework on large document sets. Initially, document pre-processing is applied on the input document sets. Here, doc-1, doc-2, …, doc-n represents the input documents for document filtering and feature extraction. Each document is filtered using the Stanford NLP library. In the pre-processing phase, each document is tokenized for word vector generation, stop word removal, stemming and n-gram processing. After the document pre-processing phase, each filtered document is given to hybrid Glove optimization model. The main and contextual key phrases of the glove optimization function are given to similarity measures for key phrase ranking. These main contextual ranked key phrases are given as input to clustering based KNN model and hybrid probabilistic based naïve Bayesian models. These models are used to improve the prediction rate or to minimize the error rate on the large documents sets.

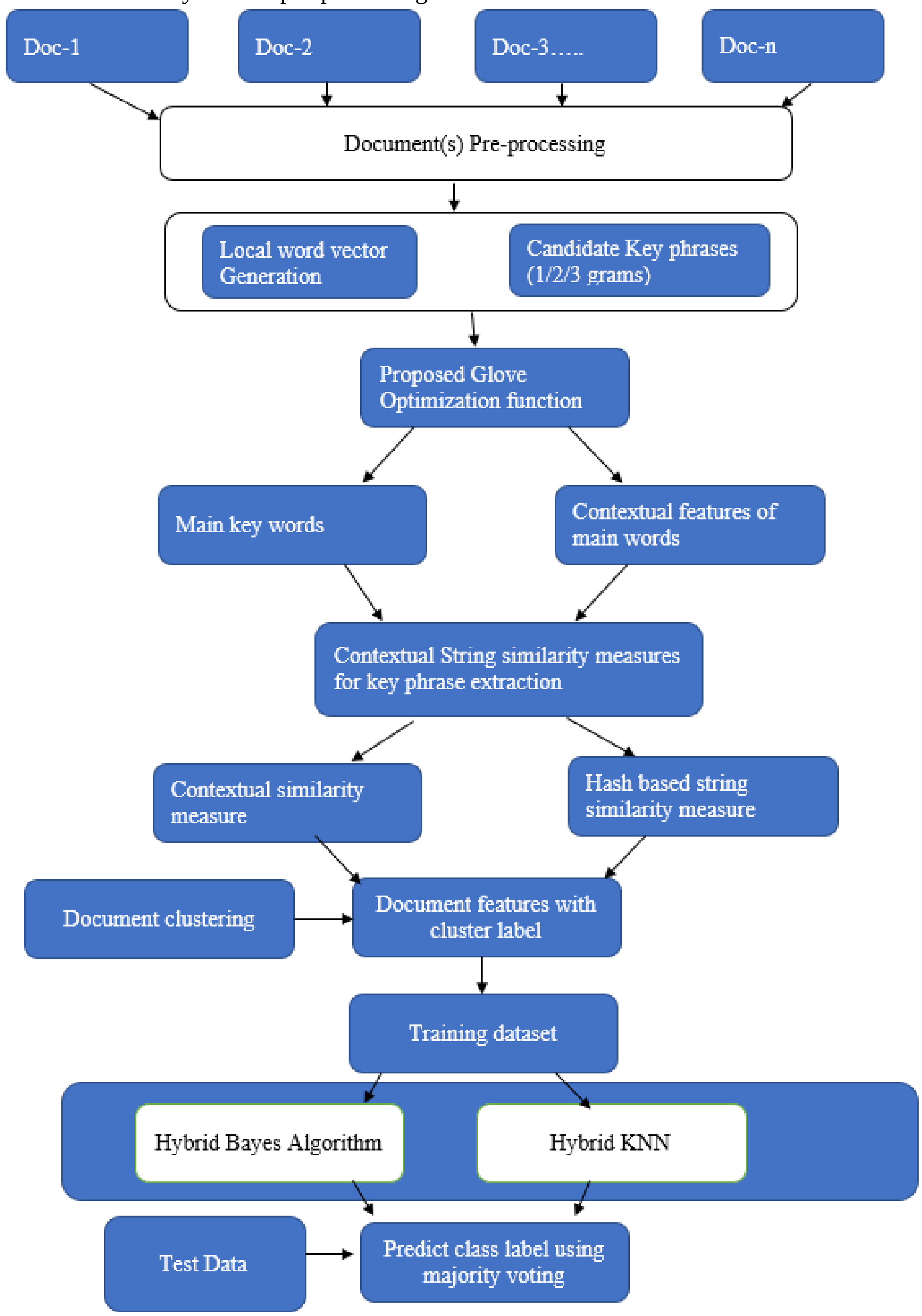

Fig. 1. Proposed Model.

In this work, an advanced cluster-based classification model is designed to improve the document cluster quality and classification accuracy. Most of the traditional document clustering-based classification models are independent of multi-class document classification due to high computational time and accuracy. In this work, a hybrid clustering measure for document classification problem is proposed to minimize the runtime(ms) and classification accuracy.

Most of the information content available on the internet is in the form of text data, so handling of text data is imperative. The method of extracting useful and non-trivial information and knowledge from unstructured text is commonly referred to in data mining. Categorization of text is a key area of study within the field of text mining. The basic purpose of categorizing text is to identify, grasp and organize volumes of text data or documents. The key problems are the complexity of natural languages, and the incredibly high dimensionality of the document feature space that solves this question of classification. Machine learning thus has a dual role: Firstly, we need an efficient data representation to store and process the vast amount of data, as well as an effective learning algorithm to solve the problem. Secondly, to identify unknown documents the accuracy and efficiency of the learning model should be high. The aim is to reduce the dimensionality curse to produce better classification accuracy as well as time consumption due to excessive processing. For the purpose of classification of text documents, the methods for sub-set selection of features employ an evaluation mechanism that is applied to each single word often known as words. There are a variety of factors in assessing the classifier's performance, such as training time, testing time, precision, precision, recall, etc. Proposed model selects a document class based on analyzing the words in the text, which consists mostly of nouns, verbs, and adjectives associated with those nouns. A similar method has been proposed with the use of POS (part-of-speech) tagging where the POS tagger can classify terms in documents by computer via the tags attached to them. A drawback of the Doc2Vec model is the high computational cost of the model construction for each document compared with Word2Vec, GloVe, and fastText. The Doc2Vec model creates a one-time only model for the n-gram text representation. Every term of the document representation vector is a collection of two or more adjacent words in a repository of documents. Another similar approach is to use a fixed section of letters, in which single pieces of letters reflect elements of every document's function vector.

Glove optimization model is used to extract n-gram local word vectors on the filtered data. This model extracts main words and its associated contextual features of main words. Finally, these main words and contextual key word vectors are given to adaptive contextual similarity and string similarity measures. GloVe encodes significance as vector offsets in an embedded space. This model measures the frequency of word co-occurrences in a broad text corpus within a specific window to produce linear significance and uses the factorization of global matrixes and local window modes. The model also has a local cost function and a weighting function to offset uncommon co-occurrences.

Proposed Glove algorithm consists of following steps:

1) Parameter initialization: Let X is the word co-occurrence matrix and each element Xij represent how often word i appears in context of word j.

w_i : Main word

w_j : Context word

b_i, b_j : main and context bias values

$$\theta = \mathrm{Min}\{b_i, b_j\}.D((w_i.b_i),(w_j,b_j))$$

2) Define soft constraints for each word pair:

$$\begin{aligned} C &= \mathrm{CostFunction} \\ &= b_i w_i^T w_j + b_j w_i^T w_j + \theta \\ &\quad -(\log(X_{ij})/\max\{\|w_i\|,\|w_j\|\}) \end{aligned}$$

$$\eta = \mathrm{weight} = f(X_{ij}) = \begin{cases} \left(\dfrac{X_{ij}}{x_{max}}\right)^{\alpha} & \text{if } X_{ij} < XMAX \\ 1 & \text{otherwise} \end{cases}$$

3) Define a cost function

$$J = \sum_{i=1}^{V}\sum_{j=1}^{V} \eta.(b_i w_i^T w_j + b_j w_i^T w_j + \theta - (\log(X_{ij})/\max\{\|w_i\|,\|w_j\|\}))^2$$

The Proposed Glove model is optimized by using the following formula.

$$\frac{\partial J}{\partial w_i} = b_i w_j C = b_i w_j (b_i w_i^T w_j + b_j w_i^T w_j + \theta - (\log(X_{ij}) / \max\{\|\mathrm{w}_i\|,\|\mathrm{w}_j\|\}))$$

$$\frac{\partial J}{\partial w_j} = b_i w_i C = b_i w_i (b_i w_i^T w_j + b_j w_i^T w_j + \theta - (\log(X_{ij}) / \max\{\|\mathrm{w}_i\|,\|\mathrm{w}_j\|\}))$$

Update w_i and w_j using learning theta.

In the contextual similarity measure, the similarity between the glove features are evaluated to find the contextual phrases in the biomedical or any textual document sets. Here, the dissimilarity index is used to compute the non-correlated features among the large number of candidate patterns. Finally, contextual glove similarity index is computed by using the dissimilarity measure.

Hash based Similarity Measure

The hash-based string similarity is given as:

Let p and q are the big integer which are randomly selected, k is the big prime integer and x is the input word vector then the hash integer of each word in the word vector is given as

H(x)=((px+q).m)xor(k)

Hash based similarity measure is used to find the connecting string similarity between the key phrases. Thus, if a sentence starting with the connecting word is included in the key-phrase, its preceding sentence is also included in the key phrase despite of its rank.

Hybrid Cluster based KNN

Input: Let k be the number of nearest neighbor documents,

D_t be the input training documents set.

Output: Classified Documents.

Procedure:

1) Read 'k' value and input training D_t.

2) Apply k-means document clustering algorithm by using the optimal weighted term distance. Compute the weighted term distance to each contextual key phrase of hybrid glove method to the test documents.

$$\psi(TF_{t,d}) = \eta. \frac{t\,f_{t,d} \times \log \frac{\sqrt{T_c}}{T_t}}{[(\sum_{t=1}^{n} t\,f_{t,d}^2) \times \log(\frac{|D|}{\sqrt{T_c}})]} \quad (1)$$

Where $T_t = \sum_{d=1}^{D} t\,f_{t,d}$ where $t\,f_{t,d}, \eta > 0$

and $T_c = \sum_{d=1}^{D} \sum_{t} t\,f_{t,d}$

3) Compute the contextual cluster similarity index between the two document sets using the cluster similarity measure.

$$S\,(CM(d_i), CM(d_j)_j) = \psi(TF_{t,d}).\frac{\sum_{k=1}^{n} t_{ik} \times t_{jk}}{\sqrt{\sum_{k=1}^{n} t_{ik}^2}\sqrt{\sum_{k=1}^{n} t_{jk}^2}}$$

4) To each test document in the training data, compute classification score using the following formula.

$$KScore\,(D_t, C_k) = \sum_{d \in DK} S\,(CM(d_i), CM(d_j)) \times P(D_i, C_j)$$

$$P(D_i, C_j) = \begin{cases} 1 & D_i \in Cj \\ 0 & D_i \notin C_j \end{cases}$$

5) To each test document in the training data, predict the classification accuracy and error rate.

6) Sort top k documents in each cluster with high classification accuracy.

Hybrid Bayesian Estimation model

In the proposed probabilistic based Naïve Bayes is used to predict the contextual main word in the hybrid glove method in the given cluster C.

$$P(C_m \mid t_{cw}) > P(C_n \mid t_{cw}) \text{ for } n \neq m$$

Using Eq (1), $P(C_m / t_{cw})$ is maximized.

According to Bayes Theory,

$$P(C_m \mid t_{cw}) = \frac{P(t_{cw} \mid C_m) P(C_m)}{P(t_{cw})}$$

In most of the test mining models, main contextual words are independent to each documents cluster. Also, as the feature space is increasing in size, the computation of priori estimations is performed using the following equations:

$$\theta(P(t_{cw} \mid c_i), P(t_{cw} \mid c_j)) = \sum_{t \in d} P(t_{cw} \mid c_i).\log_2(\frac{P(t_{cw} \mid c_i)}{P(t_{cw})} + 1) / P(t_{cw} \mid c_j))$$

$$\psi(t_{cw}) = 1 + \sum_{k} P(t_{cw} \mid c_i)^2 \cdot P(c_i \mid t_{cw})^2 \cdot (P(t_{cw} \mid c_j))^2$$

$$P(t_{cw} \mid C_m) = (\prod_{r=1}^{n} P(t_r \mid C_m). \max\{\prod_{p=1}^{m} P(C_m)) / \sum_{i,j}^{|D|} \{\theta(P(t_{cw} \mid c_i), P(t_{cw} \mid c_j)) + \theta(P(t_{cw} \mid c_i), P(t_{cw} \mid c_j))\}$$

One of the simplest machine learning algorithms is the nearest neighbor algorithm. The purpose of the education process is to store the vectors and class marks of the training documents. Documents are converted into text-classified representations in the phrase of training. The most frequently used vector space model is document representation. Each document in this model is represented by a vector, which shows the weight of one word in a document in each entry. One weighing approach is tf-idf (duration frequency-inverse frequency of the document) and the wij (duration: frequency - inverse frequency of the document).

IV. Experimental Results

The experiments are conducted on various data sets for the main sentence extraction. Every dataset is pre-processed by deleting the stop words and word stemming. In this article,we use the Wikipedia 2014 Glove and Gigaword with 5 billion vocabulary tokens. In http:/nlp.stanford.edu/ projects/glove /size, the developers of the Glove provide the term embedding vectors. We have used a window size 15 and a minimum size 10 to know the GloVe vectors. The similarity between objects is determined in the input vectors as a dot product. Co-occurrence is a strong foundation which encompasses many forms of element similarity. For word similarity, we used the stringsim and contextual similarity measures to demonstrate our model's capacity, a well-known dataset for the English evaluation of similarity. For the evaluation of the proposed model, experimental results are being simulated on text documents such as real time biomedical databases, ChEBI, biocause, PHAEDRA corpus. The cluster score and main contextual feature obtained in iteration 1 for ChEBI is furnished in Appendix-I.

Table I illustrates the experimental analysis of proposed clustering-based document classification model to the conventional classification algorithms using true positive rate. In these results, proposed hybrid cluster based naïve Bayesian model has better true positive rate than the conventional models on different text document datasets.

Fig. 2 illustrates the experimental analysis of proposed clustering-based document classification model to the conventional classification algorithms using true positive rate. In these results, proposed hybrid cluster based KNN model has better true positive rate than the conventional models on different text document datasets.

TABLE I. PERFORMANCE RESULTS OF PROPOSED CLUSTERING-BASED HYBRID NAÏVE BAYESIAN ALGORITHM TO THE CONVENTIONAL MODELS USING TRUE POSITIVE RATE

Models	Reuters-21587	SemEval	Ohusumed	Biomedical
SVM	0.81	0.85	0.87	0.91
KNN	0.83	0.83	0.89	0.9
TFID	0.85	0.91	0.91	0.9
Naive_Bayes	0.87	0.85	0.92	0.92
DCCC	0.956	0.923	0.901	0.914
HCNB	0.96	0.94	0.95	0.97

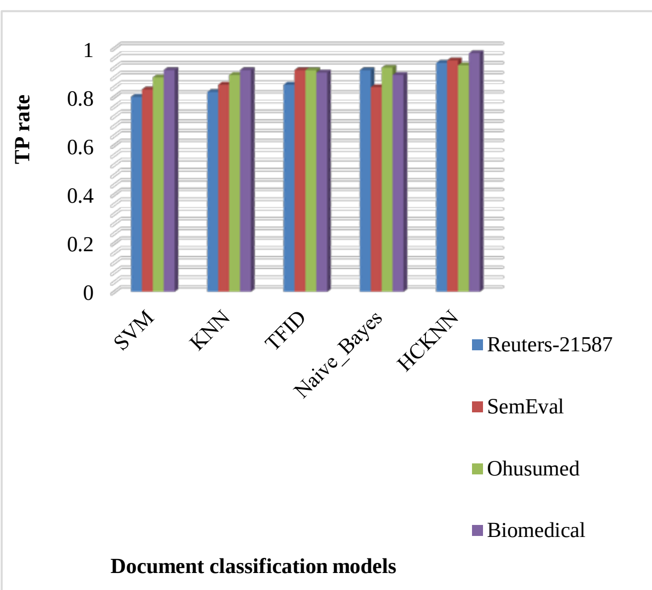

Fig. 2. Performance Results of Proposed Clustering based Hybrid KNN Algorithm to the Conventional Models using True Positive Rate.

TABLE II. PERFORMANCE RESULTS OF PROPOSED CLUSTERING-BASED HYBRID NAÏVE BAYESIAN ALGORITHM TO THE CONVENTIONAL MODELS USING ACCURACY MEASURE

Models	Reuters-21587	SemEval	Ohusumed	Biomedical
SVM	0.77	0.79	0.86	0.89
KNN	0.83	0.84	0.91	0.89
TFID	0.86	0.9	0.9	0.89
Naive_Bayes	0.91	0.86	0.9	0.9
DCCC	0.935	0.962	0.932	0.957
HCNB	0.95	0.97	0.94	0.97

Table II illustrates the performance analysis of proposed clustering-based document classification model to the conventional classification algorithms using accuracy measure. In these results, proposed hybrid cluster based naïve Bayesian model has better average accuracy rate than the conventional models on different text document datasets.

Fig. 3 describes the performance analysis of proposed clustering-based document classification model to the conventional classification algorithms using accuracy measure. In these results, proposed hybrid cluster based KNN approach has better average accuracy rate than the conventional models on different text document datasets.

Fig. 4 illustrates the performance analysis of proposed clustering-based document classification model to the conventional classification algorithms using error rate measure. In these results, proposed hybrid cluster based naïve Bayesian model has better average accuracy rate than the conventional models on different text document datasets.

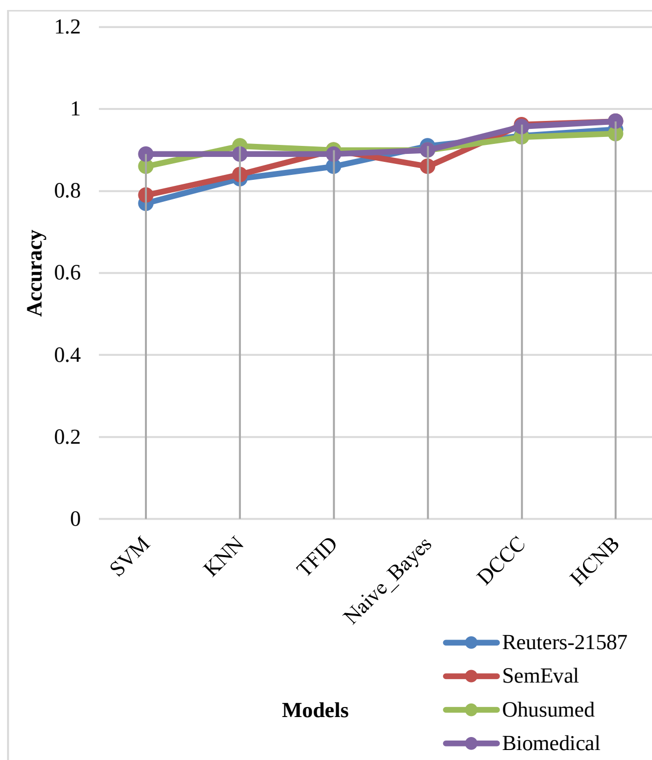

Fig. 3. Performance Results of Proposed Clustering-based Hybrid KNN Model to the Conventional Models using Accuracy Measure.

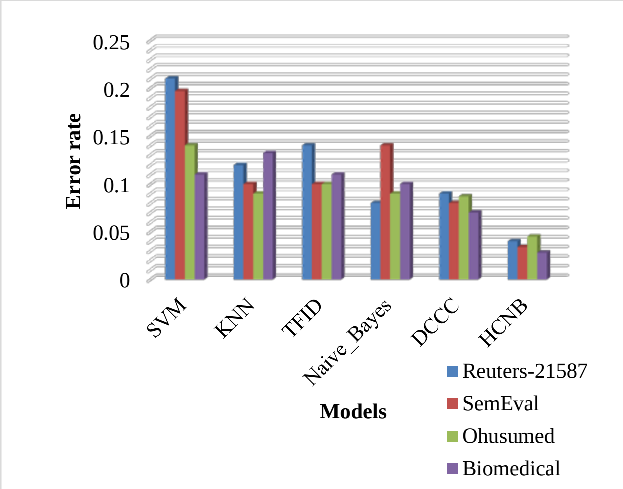

Fig. 4. Performance Results of Proposed Clustering-based Hybrid Naïve Bayesian Model to the Conventional Models for Error Rate Estimation.

TABLE III. COMPARATIVE ANALYSIS OF PRESENT TECHNIQUE TO THE CONVENTIONAL TECHNIQUES BY USING ERROR RATE ESTIMATION ON DIFFERENT MICROARRAY DATASET

Models	Reuters-21587	SemEval	Ohusumed	Biomedical
SVM	0.21	0.197	0.14	0.11
KNN	0.12	0.1	0.09	0.132
TFID	0.14	0.1	0.1	0.11
Naive_Bayes	0.08	0.14	0.09	0.1
DCCC	0.09	0.08	0.087	0.07
HCNB	0.04	0.034	0.045	0.028

Table III describes the performance analysis of proposed clustering-based document classification model to the conventional classification algorithms using error rate measure. In these results, proposed hybrid cluster based KNN approach has better average accuracy rate than the conventional models on different text document datasets.

V. CONCLUSION

Document classification is one of the major problems in large and high dimensional feature space. As the size of contextual features in the documents sets increases, it is difficult to classify the documents using the traditional glove, TF-D and word2vec methods. In this paper, an advanced document clustering-based classification model is implemented on the large inter and intra feature variation document sets. In this work, a hybrid document clustering similarity index is optimized to find the essential key document clusters based on the contextual keywords. Experimental results show that the clustering-based document classification models have better statistical performance than the conventional approaches on large document sets.

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APPENDIX-I

Cluster Score : which its vector value :0.96

Cluster Score : were its vector value :0.952

Cluster Score : separated its vector value :0.961

Cluster Score : by its vector value :0.95

Cluster Score : a its vector value :0.938

Cluster Score : washout its vector value :0.941

Cluster Score : period its vector value :0.926

Cluster Score : of its vector value :0.934

Cluster Score : 4 its vector value :0.972

Cluster Score : weeks, its vector value :0.931

Cluster Score : was its vector value :0.923

Cluster Score : used. its vector value :0.974

Cluster Score : its vector value :0.935

Cluster Score : In its vector value :0.958

Cluster Score : each its vector value :0.95

Cluster Score : phase its vector value :0.97

Cluster Score : ten its vector value :0.942

Cluster Score : healthy its vector value :0.922

Cluster Score : volunteers its vector value :0.973

Cluster Score : took its vector value :0.961

Cluster Score : 200 its vector value :0.946

Cluster Score : mg its vector value :0.946

Cluster Score : itraconazole its vector value :0.964

Cluster Score : or its vector value :0.933

Cluster Score : matched its vector value :0.923

Cluster Score : placebo its vector value :0.969

Cluster Score : orally its vector value :0.97

Cluster Score : once its vector value :0.959

Cluster Score : daily its vector value :0.952

Cluster Score : for its vector value :0.958

Cluster Score : 4 its vector value :0.951

Cluster Score : days its vector value :0.947

Cluster Score : according its vector value :0.941

Cluster Score : to its vector value :0.965

Cluster Score : a its vector value :0.925

Cluster Score : randomization its vector value :0.95

Cluster Score : schedule. its vector value :0.952

Cluster Score : its vector value :0.926

Cluster Score : On its vector value :0.94

Cluster Score : day its vector value :0.929

Cluster Score : 4, its vector value :0.949

Main-Contextual Works List :===> 1) 2) The 3) 0.040703042514465194

Main-Contextual Works List :===> 1) 2.6-fold 2) 2.0-fold 3) 0.02630626620960846

Main-Contextual Works List :===> 1) cerivastatin, 2) major 3) 0.004520272696979648

Main-Contextual Works List :===> 1) half-life 2) cerivastatin 3) 0.010059523995966884

Main-Contextual Works List :===> 1) days 2) for 3) 0.030376280419389695

Main-Contextual Works List :===> 1) days 2) according 3) 0.03075857667846457

Main-Contextual Works List :===> 1) were 2) two 3) 0.018200219160994166

Main-Contextual Works List :===> 1) metabolite 2) active 3) 0.02934636541187912

Main-Contextual Works List :===> 1) metabolite 2) M-23, 3) 0.03636079620998193

Main-Contextual Works List :===> 1) increased 2) 1.8-fold 3) 0.002126193197175103

Main-Contextual Works List :===> 1) concentrations 2) its 3) 0.022965243547397464

Main-Contextual Works List :===> 1) concentration 2) of 3) 0.042554880058576515

Main-Contextual Works List :===> 1) HMG-CoA 2) reductase 3)

```
0.01220133757689449
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```

```
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 Main-Contextual Works List :===> 1) and 2) reductase 3) 0.012228039361377256
 Main-Contextual Works List :===> 1) 4 2) to 3) 0.00328600130796709
 Main-Contextual Works List :===> 1) (P 2) increased 3) 0.03118034855179173
Iteration #1 , cost = 244.0632399474855
 Avg Features 48
 Runtime(ms) of Features 4617.0
 Runtime(ms) of Similarity rank 4927.0
Classification accuracy :98.4
```

Super-Resolution using Deep Learning to Support Person Identification in Surveillance Video

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***Abstract*—Recently, video surveillance systems have been perceived as important technical tools that play a fundamental role in protecting people and assets. In particular, the recorded surveillance video sequences are used as evidence to solve violation, theft and criminal cases. Therefore, the identification of the person present on the crime scene becomes a critical task. In this paper, we proposed a Deep learning-based Super-Resolution system that aims to enhance the faces images captured from surveillance video in order to support suspect identification. The proposed system relies on an image processing technique called Super-Resolution that consists of recovering high-resolution images from low-resolution ones. More specifically, we used the Very-Deep Super-Resolution (VDSR) neural network to enhance the image quality. The proposed model was trained with CelebA faces dataset and used to enhance the resolution of the QMUL-SurvFace dataset. It yielded a Peak Signal-to-Noise Ratio (PSNR) improvement of 7% and Structural Similarity Index (SSIM) improvement of 3%. Most importantly, it increased the face recognition rate by 45.7%.**

Keywords—Deep learning; image processing; super-resolution; surveillance video

I. Introduction

Nowadays, video surveillance cameras are crucial for ensuring people's safety and security. In fact, they become an essential evidence for investigating security related cases. More specifically, the identification of the persons recorded in the surveillance video becomes decisive in solving such cases. However, the involved person identification is not always possible due to the low-resolution (LR) stored video frames.

The resolution that refers to the amount of details can be defined as the number of pixels per frame length unit [1]. Thus, the resolution increases with the number of pixels [2]. However, although surveillance cameras can record high-quality videos, they have limited storage space. Accordingly, the size of the recorded video is decreased, which leads to quality degradation. An obvious technical solution would be to increase the storage capacity, but this would be very expensive. In addition, the LR image could suffer from further quality degradation when the scene is crowded, or the suspect's face is far away from the camera since zooming in the image would degrade the quality of the region of interest. Furthermore, there are more factors that may affect the image quality like bad weather or the lightening conditions of the scene.

One of the ways to alleviate the problem of a low resolution (LR) image is to generate a high-resolution (HR) image from its corresponding single LR one by learning the relationship between them. This process is called Single Image Super-Resolution (SISR). The Super-Resolution (SR) problem is considered as an ill-posed problem since there are several ways to construct an HR image from a single LR one [3]. Example-based SR is a common class of such algorithm that uses a prior knowledge obtained by learning a huge dataset of LR-HR image pairs [4], then use this knowledge to predict fine details in real-world images. Recently Convolutional Neural Networks (CNNs) have been proposed as a solution to solve the Super-Resolution problem [5][6][7].

In this paper, we improve the performance of the LR faces images captured from surveillance recorded videos by adopting a Very-Deep Super-Resolution (VDSR) convolutional neural network-based system [8]. The proposed system is trained to learn the estimation of the difference between an HR image and an LR image. This difference called residual image [9] is added to the LR one to obtain the final HR image.

II. Related Works

Recently, SISR systems using deep learning for both generic images and faces images enhancement have been reported in the literature [4][10] [11].

A. SISR for Generic Images using Deep Learning

The authors in [6], proposed an SR system called Super-Resolution Convolutional Neural Network (SRCNN). The input of this approach is a single LR image up-sampled using bicubic interpolation. The input image is then converted to its Y-channel. The system directly produces the HR image. The deep learning architecture consists of three convolutional layers. More specifically, the feature extraction is applied in the first convolutional layer. The second layer applies a fully connected non-linear operation, which maps feature maps to HR patches. The last layer merges the predictions to eventually produce the HR image. Fig. 1 illustrates SRCNN architecture where f_s are the filters sizes.

In the Efficient Sub-Pixel Convolutional Neural Network (ESPCN) approach [12], an HR image is convolved using Gaussian filter and downscaled by a factor r to produce an LR image, which is used as an input to the network. The system architecture consists of three hidden layers. The first two layers are convolutional layers for extracting features and the last layer is a sub-pixel convolution layer in which the LR image is up-sampled by a factor r via a pixel shuffle operation that rearranges pixels to produce HR output. The pixel shuffle operation converts $r^2\,(height \times width \times channel)$ LR feature representation to a $(r\,height \times r\,width \times channel)$

HR image as depicted in Fig. 2. An upscaling factor of 3 ($r = 3$), is used such that for every pixel in the LR image there are 3×3 pixels (one pixel from each channel) in the HR image. Unlike SRCNN [6], the only upscaling occurs in the last layer, so the authors could extract the feature maps in LR space using small filters. Therefore, the number of computations can be reduced, and eventually, real-time performance can be achieved.

In [13], the authors designed an SR system called Orientation-aware Deep Neural Network for Real Image Super-Resolution. The system uses as input real-world captured LR image after converting it to its corresponding Y-channel. The network learns to output a residual image. The architecture consists of three layers CNN and same as [12] and has a pixel-shuffle operation. Fig. 3 displays the network architecture. In Fig. 3, I^{LR} and H^{HR} denote the LR and HR images, respectively. At the input layer, an operation called de-pixel shuffle is performed on the input, it arranges the image by converting its size from $height \times width \times channel$ to $\frac{height}{r} \times \frac{width}{r} \times r^2 channel$, where r is the scaling factor. This operation reduces the image size and increases the number of channels in order to accelerate the speed of the network. Convolutional layers extract three orientation-aware features by using horizontal, vertical, and diagonal kernels. After the first convolutional layer, there are 16 orientation-aware feature extraction and channel-attention modules (OAMs) that are used to fuse the orientation-aware features to produce more distinctive features that are used for LR-HR mapping. At Each OAM, a local residual unit is used to accelerate the training process. OAM architecture is shown in Fig. 4, F^{ver}, F^{hor} and F^{dia} denote the extracted features, and F^{fuse} is the fused features, while F^{CA} is the features after being enhanced by the attention channel. At the end of the network, a pixel shuffle operation is performed at the final output to reconstruct the HR image.

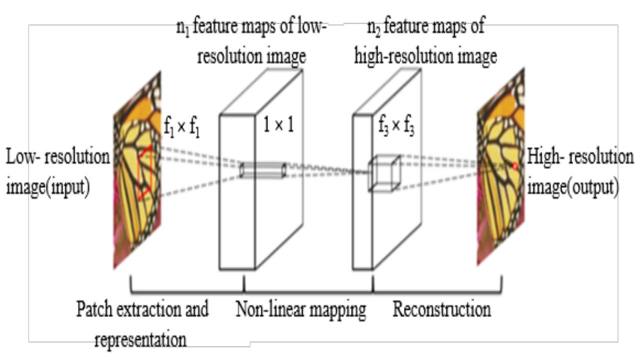


Fig. 1. The Architecture of SRCNN [6].

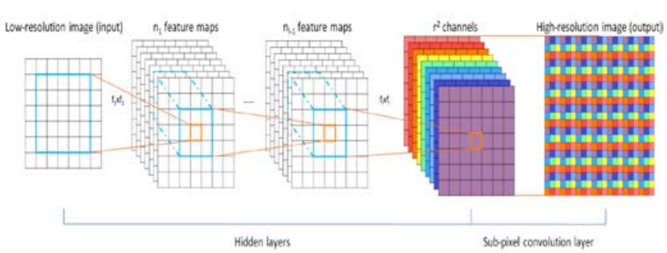


Fig. 2. The Architecture of ESPCN [12].

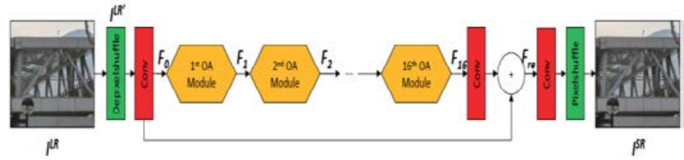


Fig. 3. The Architecture of Orientation-aware Deep Neural Network [13].

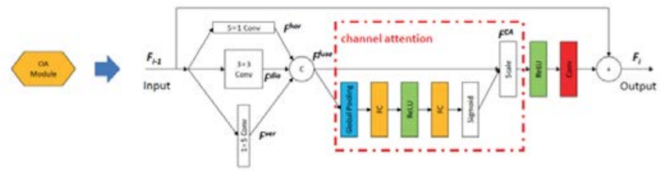


Fig. 4. The Architecture of OAM [13].

The authors in [14] introduced a system called Deep CNN with Skip Connection and Network in Network (DCSCN). Similarly, to [6] and [13], the network processes the original image's Y-channel and produces channels of corner pixels of each up-sampled pixel named 4ch (square of the scale factor channels). As displayed in Fig. 5, the network consists of two sub-networks: feature extraction network and reconstruction network. The feature extraction network receives as input image's pixels and extracts features of each pixel in seven CNN layers. Each layer is connected to the next layer and the reconstruction network by Skip connections. So, each layer's output is sent to the next layer and the reconstruction network simultaneously. As the reconstruction network receives extracted features, three parallelized CNNs (Network in Network) up-sample and reconstruct the image features and pass the output to the last CNN layer. This last layer outputs 4 channel image which is reshaped to construct an intermediate HR image. At the end, the intermediate HR image is added to the bicubic up-sampled input image to obtain the final HR image.

In [15] the authors proposed the Deep Recursive Residual Network (DRRN) network. The input is an LR image, which is generated using bicubic interpolation to the color components of the image. The deep neural network model learns to output the residual image. For this purpose, the proposed system architecture consists of 52 convolutional layers. Moreover, it has a recursive mechanism that contains two residual units. The first one is a global residual, which estimates the HR image from combining the input and the residual of the network. The second one is a local residual. It is located at every few stacked layers. Fig. 6 shows DRRN architecture.

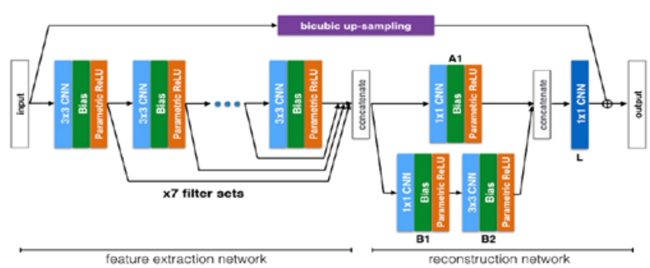


Fig. 5. The Architecture of DCSCN [14].

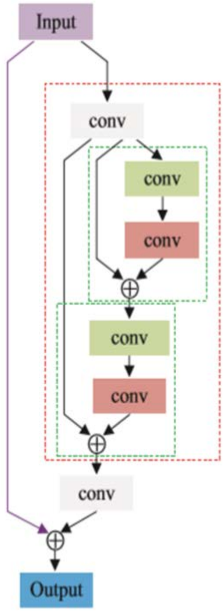


Fig. 6. The Architecture of DRRN [15].

In [8], the authors proposed a Very Deep Super-Resolution Convolutional Networks (VDSR). The input is an interpolated low-resolution (ILR) image. It is produced by extracting the Y channel from the HR image, then down-sampling it by bicubic interpolation, after that, the obtained LR image is up-sampled to match the original size of its HR. The network's output is the residual image. The network consists of 20 sequential convolutional layers which means it uses large information for HR image reconstruction (large receptive field). Also, each hidden layer has 64 filters of size 3×3×64 for feature extraction. The network architecture is shown in Fig. 7.

B. SISR for Face Images using Deep Learning

The authors in [16] proposed the Multi-Scale Competitive Convolutional Neural Network. It is a three layers CNN. The HR image is down-sampled then up-sampled using bicubic interpolation to obtain an LR image which is conveyed as input to the deep neural network. The system learns to output the residual image. Fig. 8 shows the system architecture. The first two layers have three parallel competitive multi-scale filters. These filters provide high contextual information for the SR image. Each layer produces three groups of features. These groups are then arranged to obtain non-overlapping groups. Then, the maxout activation function is applied to select the input for the next layer. The last layer is responsible for reconstructing the final image. This network uses faces images as training examples as well as generic images.

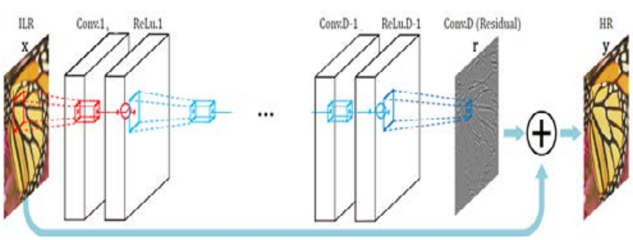


Fig. 7. The Architecture of VDSR [8].

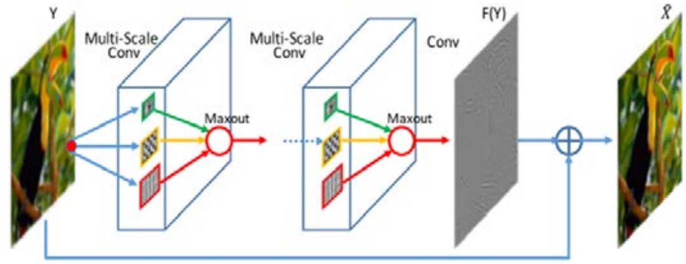


Fig. 8. The Architecture of the Multi-Scale Competitive Convolutional Neural Network [16].

The authors in [17] suggested the Attribute Augmented Convolutional Neural Network (AACNN) system to solve the SR problem. The input of this system is a down-sampled LR image of size 14×12 along with a feature attribute vector. As for the output, it produces an HR image with a size of 112×96. The architecture of the system consists of two sub-networks as shown in Fig. 9. They are generator and feature-extraction networks. The feature extraction network consists of two sub-branches A and B. A is responsible for extracting the fine-grained feature from the LR input image using three convolution layers. On the hand, B takes as an input the feature attribute vector with a dimension of 1×1×38 and expands its dimension from 38 to 504 using a fully connected layer. It is then reshaped to 14×12×3 to match the size of the LR image. The next convolution layers work as branch A. Then, branch A and B are both combined as one image to be fed to the generator network. In other words, the generator network learns the mapping between the LR and HR images through the features that it receives from the feature extraction. This helps the generator get a clearer vision of the HR image while up-sampling the image through the network using deconvolution layers. This yields the generation of the final HR image with a size of 112×96.

Unlike the system presented in [17], which is fully parallel, the authors in [18] proposed a partially parallelized network called Bi-channel CNN. The network receives a 48×48 bicubic interpolated LR image as input and learns to output an intermediate image reconstructed of the extracted face features. Fig. 10 represents the proposed architecture. Same as in [17], the network consists of two sub-networks: feature extractor and image generator. Feature extractor extracts input face features with three convolutional layers. The output is passed to the image generator which contains four fully connected parallelized layers in two groups. The first group reconstructs the image's features to produce an intermediate image, while the second group predicts the fusion coefficient α which controls the integration of the two channels of information. They are the up-sampled input image and the intermediate image.

As reported above, various SR approaches based on deep learning have been proposed in the literature. Some of these approaches are designed for generic image SR [6, 12, 13, 14, 15] while others are designed for the specific application of faces images SR enhancement [16, 17, 18]. In the following, we discuss the reported approaches in terms of context, convergence, and scale factor.

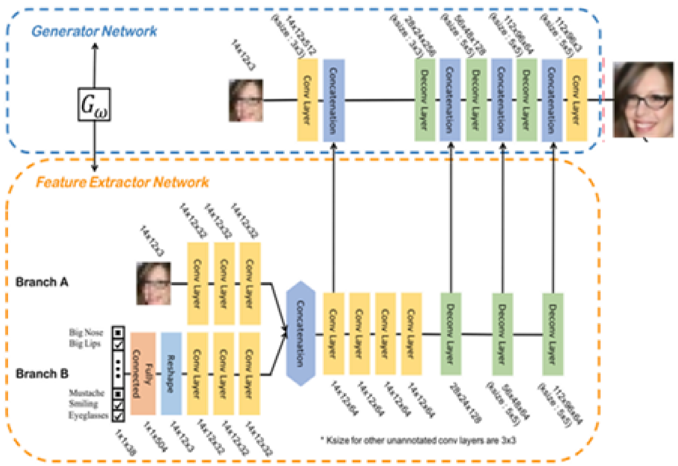


Fig. 9. The Architecture of AACNN [17].

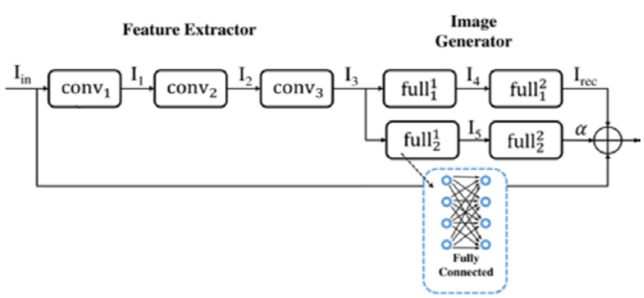


Fig. 10. The Architecture of Bi-Channel CNN [18].

Context: Most large depth networks use a large amount of contextual information. This allows retrieving more image details in order to obtain the HR image. The network in [6] relies only on the context of small regions of the image, which is inefficient for obtaining details of large-scale image. On the other hand, the works reported in [8, 15] use a large amount of contextual information allowing the reconstruction of HR images with more details.

Convergence: Since the LR image and the HR image are similar, learning the residual instead of learning the HR image reduces the required computations. The works reported in [8, 13, 14, 15, 16] learn residual images which speeds-up the training process.

Scale-factor: for real-world applications, image scales differ naturally depending on the application. However, most reported approaches consider only a single specified scale. On the other hand, the work in [8] proposed a system that handles multi-scale images for more realistic model.

A summary of the related works is presented in Table I. It compares the different approaches based on these characteristics: The preprocessing process applied to the input, the input image type, the proposed architecture, the training dataset, and the performance results. The performance of each network is measured using Peak Signal-To-Noise Ratio (PSNR) [19] or Structural Similarity Index (SSIM) [20]. As reported in Table I, the performance of the reported approaches shows that there are still ways of improvement.

III. Very Deep Super Resolution Network Structure

The Very Deep Super Resolution, VDSR, is a Convolutional Neural Network (CNN). It is designed to solve the SR problem for generic images [8]. The network structure consists of an input layer, twenty cascading pairs of hidden layers and an output layer. Each pair consists of a convolutional layer followed by a rectified linear unit. The network structure is illustrated in Fig. 11.

A. Input Layer

It is the first layer. It takes as an input an interpolated low-resolution (ILR) image with only one channel since the network is trained using the luminance channel of the input. The layer operates on the input. The size of the patches depends on the network receptive field which size is equal to the input image, in order to let the field views all the high features of the image [9].

B. Hidden Layers

The image input layer is followed by 19 alternating convolutional and rectified linear unit (ReLU) layers. The convolutional layer contains 64 filters each of size 3×3×64. They are applied to 3×3 regions across 64 channels of the input to extract features. The units (neurons) in the first convolutional layer are connected to local regions of the input image, and so on, each unit in convolutional layer m is connected to a subset of units of convolutional layer $m-1$. Thus, each unit has its own receptive field with respect to its input. This design implies that the learned filters of the network generate the highest response to a local input feature.

When the number of sequential layers is large, the filters by time become global, which leads to increase the size of the receptive field by 2 in height and width, the size is calculated by the formula: $(2D+1)(2D+1)$, where D is the number of the convolutional layer. In VDSR, there are 20 convolutional layers, so the receptive field (as well as the size of the patch) is 41 by 41. In SR, a large receptive field means large contextual information is taken into consideration when predicting image details [8].

C. Output Layer

As for the final layers, the penultimate layer is a convolutional layer, it has only one filter of size 3×3×64. The convolutional layer is followed by the regression unit.

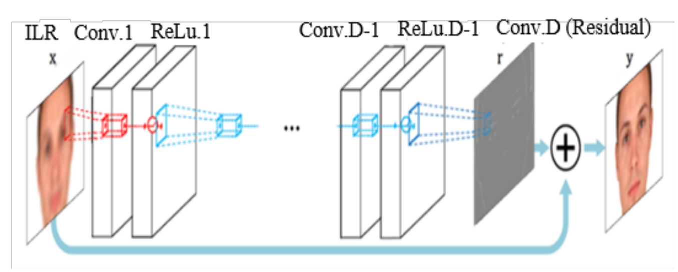


Fig. 11. VDSR Network Structure.

TABLE I. A BRIEF SUMMARY OF THE RELATED WORKS

Reference	Preprocessing	Image Type	Architecture	Number of Layers	Training Datasets	Results
[6]	Bicubic interpolation and Y channel extraction	Generic	CNN	3 convolutional layers	ImageNet [25]	PSNR = 29
[12]	Gaussian filter and down sampling	Generic	CNN with one sub-pixel convolutional layer.	3 convolutional layers	ImageNet [25]	PSNR = 29.495
[13]	Y channel extraction	Generic	CNN, 16 channel attention modules, pixel shuffle and de-pixel shuffle layer.	3 conventional layers	NTIRE2019 Real Super-Resolution challenge [26]	PSNR= 29.35 SSIM= 0.8599
[14]	Y channel extraction	Generic	Partially parallel Deep CNN with Skip Connection	11 conventional layers	Berkeley Segmentation Dataset [27]	PSNR = 37.02
[15]	Bicubic interpolation	Generic	DRRN with Several recursive blocks, followed by a convolutional layer	52 convolutional layers	Berkeley Segmentation Dataset [27]	PSNR = 28.14 SSIM = 0.788
[8]	Bicubic interpolation and Y channel extraction	Generic	CNN	20 conventional layers	Dataset in [28] and Berkeley Segmentation Dataset [27]	PSNR = 37.53 SSIM = 0.9587
[16]	Bicubic interpolation and Y channel extraction	Faces	Parallel competitive multi-scale filters CNN	3 conventional layers	Dataset in [29] and Berkeley Segmentation Dataset [27]	PSNR = 32.42 SSIM = 0.7808
[17]	Down sampling	Faces	2 Parallel CNN sub-networks	12 conventional layers	CelebA [23]	PSNR= 27.4007 SSIM= 0.8036
[18]	Bicubic interpolation	Faces	Partially parallel Bi-channel CNN	3 conventional layers and 4 fully connected layers	Their own [18]	PSNR = 34.63 SSIM = 0.92

IV. SUPER-RESOLUTION USING DEEP LEARNING TO SUPPORT PERSON IDENTIFCATION IN SURVEILLANCE VIDEO

SISR is considered a critical issue in many applications that deal with LR images and need to extract high information details from them. Face recognition from surveillance camera records is one of the applications that suffer from such a problem, thus making the task of identifying the persons present in the scene difficult. For this purpose, we propose a SISR technique that uses Very-Deep Super-Resolution (VDSR) system to recover HR images from LR images [8]. VDSR has been used in [8] with generic images while the focus of this paper is on faces images captured by surveillance videos. Conveying the obtained HR images to a face recognition system would enhance the performance of the recognition system since the HR image contains more details.

As reported in the literature, CNN has been successfully used to learn HR image from LR image [6]. However, CNN based approaches have some drawbacks. First, they only preserve the contextual information over small image regions. Second, the training process is very long since the input image has to go through all layers until it reaches the output layer. Third, the systems are trained using a unique image scale, which makes them incapable of handling images of different scales.

In order to alleviate the previously mentioned drawbacks, we propose to use the VDSR architecture [8] to learn the residual image. It is a very deep architecture that consists of twenty sequential layers. Furthermore, it organizes many adjacent small filters over the input image that preserves the contextual information over large regions of the image. These proprieties would yield a better SR system. In fact, since it uses a large receptive field, it considers the contextual details spread over large regions of the input. This increases the amount of context a neuron can see from the input, to map it to the output [21]. Moreover, the proposed system learns the residual image. This yields its convergence in a reasonable time compared to the systems that learn the HR image directly. In addition, it has been shown in [8] that the performance of the residual network is higher than the non-residual one. Furthermore, the proposed system uses a single network for training multi-scaled data. Furthermore, it has been empirically shown in [8] that the performance of the network increases with its depth. In other words, very deep CNN improves SR system performance.

A. Training Framework

For training the VDSR network, the first step is processing the training images. The images are HR, they are transformed into YCbCr space, and then, the luminance channels (Y) of them are extracted. After that, the images are down-sampled using different scale factors to obtain LR images. The LR images are resized by bicubic interpolation [22] to make them match the original sizes of their HR images. Lastly, the residual images are calculated, and they are stored along with the resized images (LR images) [9].

When the training phase is initiated, the network's weights (filters) values are randomly generated and the biases are initialized to zeros. The network learns to output the estimated residual image of the input by minimizing the loss function which is the mean squared error. This function is calculated at the last layer and is defined as.

$$L = \frac{1}{2}\|r - f(x)\|^2 \quad (1)$$

where r is the residual image and (x) is the network predicted output. The network is able to minimize this function by mini-batch gradient descent that uses the backpropagation method [8]. In addition, the network is trained using multiple scale images. This is achieved by dividing the image into non-overlapping sub-images and having an input patch size equal to the receptive field. One mini-batch contains 64 sub-images of the same scale [8].

V. Experiments

A. Datasets Description

CelebA [23] and QMUL-SurvFace [24] benchmark datasets are used to train and assess the performance of the proposed system. CelebA [23] is a faces dataset for celebrity faces images. It includes 10,177 of identities and 202,599 of face images. The dataset covers different backgrounds with pose variations. As for the QMUL-SurvFace benchmark dataset [24], it includes large scale surveillance faces images. It has been introduced as a benchmark for the surveillance face recognition challenge 2019. This benchmark contains 463,507 faces images of 15,573 different persons captured in various real-world scenes with large space and time variations. The set of images are LR images by nature. In other words, they are not the result of down-sampling HR images.

As the faces images of CelebA dataset [23] are HR, the dataset is used for training and testing the VDSR network. However, QMUL-SurvFace [24] dataset cannot be used to train the network since it has only LR faces images. Instead, it is used to test the trained system with a face recognition system [30] as an evaluation tool.

B. Experimental Setting

A network depth of 20 and training batches of size 64 are used as in [8]. Moreover, the Momentum parameter is set to 0.9 and the decay parameter to 0.0001. Moreover, the number of epochs is determined by early stopping technique, where a validate set is tested by the model after a certain number of epochs to check for overfitting occurrence and stop the training then. The learning rate is set to 0.1. In addition, we use a zero-padding technique.

C. Experiment 1

In this experiment, we trained the VDSR system using a subset of the first 110,000 images from CelebA dataset [23]. As a preprocessing step, CelebA dataset images were cropped to get rid of the background and include only the face. The images were originally of size 218×178 and became 116×105. The dataset was randomly split into a training set of 66,000 images and test set of 44,000 images. The VDSR was trained to handle three scale factors, 2, 3 and 4. So, the training images were down-sampled by these scale factors, then up-sampled by bicubic interpolation [22] and fed to the model.

The training set was provided as input to the VDSR system to train the network. The model was trained over 5 epochs. Once the training phase was finished, the test set was conveyed as input. PSNR [19] and SSIM [20] are used to compare the obtained HR images to the target ones, the training and testing results with respect to each scale factor are reported in Table II and Table III, respectively. We can see that the model's results outperform the bicubic interpolation's results [22]. Also, we can observe from the tables that as the scale factor is smaller as the performance results are better. It can be explained by the fact that the SR problem is simpler as the down-sampling factor is small.

Fig. 12 and Fig. 13 display the performance comparison of PSNR and SSIM, respectively. They show a comparison between the testing results of the trained VDSR model using CelebA, the training results of the trained model using CelebA, the testing results for bicubic interpolation, and the training results for bicubic interpolation.

TABLE II. Performance of VDSR Model and Bicubic Interpolation on the Training Set

Scale factor	VDSR Model		Bicubic Interpolation	
	PSNR	***SSIM***	***PSNR***	***SSIM***
×2	32.426770	0.971939	30.259453	0.957807
×3	27.726198	0.934817	26.064288	0.913828
×4	27.553009	0.923985	25.706819	0.895698

TABLE III. Performance of VDSR Model and Bicubic Interpolation on the Test Set

Scale factor	VDSR Model		Bicubic Interpolation	
	PSNR	***SSIM***	***PSNR***	***SSIM***
×2	32.417566	0.971969	30.259927	0.957875
×3	27.729268	0.934914	26.070009	0.913938
×4	27.551795	0.924075	25.711985	0.895859

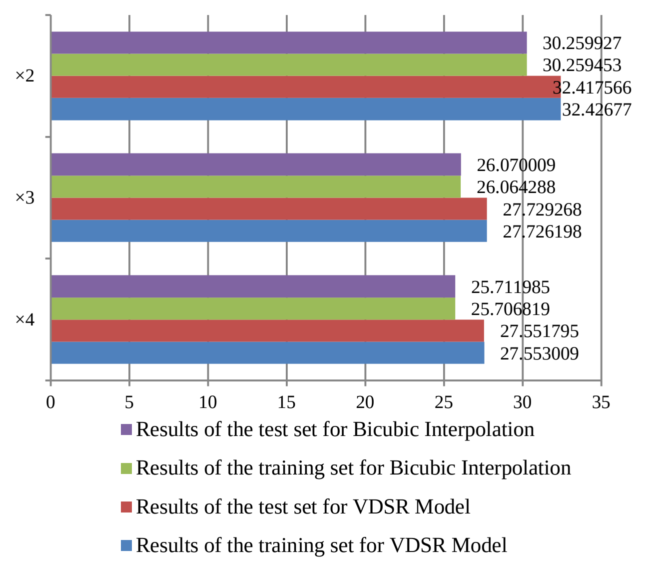


Fig. 12. PSNR Performance Comparison between the Training and Testing Results of VDSR Model and Bicibic Interpolation.

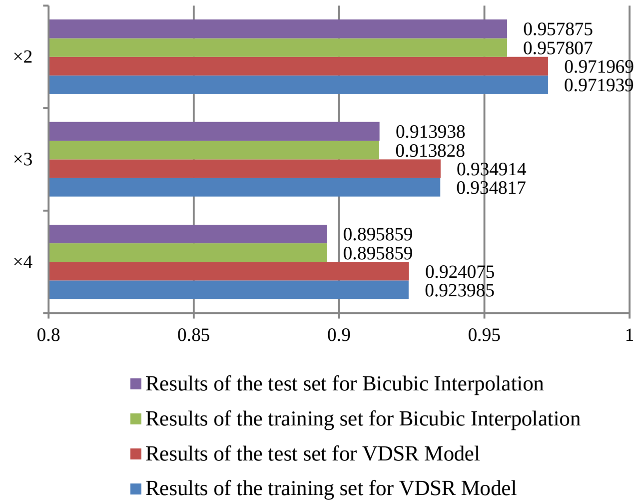


Fig. 13. SSIM Performance Comparison between the Training and Testing Results of VDSR Model and Bicibic Interpolation.

Fig. 14 shows a sample image from CelebA. Fig. 15, Fig. 16 and Fig. 17 display the results of the SR enhancement using the multi-scaled VDSR model with respect to scale factors 2, 3, and 4. For each considered scale factor, the LR image obtained by down-sampling the original image by the corresponding scale factor, the learned residual image, and the resulting HR image are displayed.

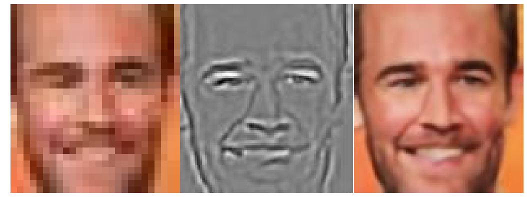
Fig. 14. Sample Cropped Image from CelebA.

(a) (b) (c)

Fig. 15. Results of the SR Enhancement using the Multi-Scaled VDSR Model with Respect to Scale Factor 2 on the Sample Cropped Image from CelebA . (a) LR Image Obtained by Down-Sampling the Original Image by a Scale Factor of 2, (b) the Learned Residual Image, and (c) the Resulting HR Image.

(a) (b) (c)

Fig. 16. Results of the SR Enhancement using the Multi-Scaled VDSR Model with Respect to Scale Factor 3 on the Sample Cropped Image from CelebA . (a) LR Image Obtained by Down-Sampling the Original Image by a Scale Factor of 3, (b) the Learned Residual Image, and (c) the Resulting HR Image.



(a) (b) (c)

Fig. 17. Results of the SR Enhancement using the Multi-Scaled VDSR Model with Respect to Scale Factor 4 on the Sample Cropped Image from CelebA . (a) LR Image Obtained by Down-Sampling the Original Image by a Scale Factor of 4, (b) the Learned Residual Image, and (c) the Resulting HR Image.

D. *Experiment 2*

This experiment is conducted on the QMUL-SurvFace benchmark dataset [24]. Since this dataset has only LR face images, it cannot be used to train the VDSR. Instead, it was used to test the trained system using CelebA dataset [23] obtained from experiment 1. In other words, using the model obtained after training the network in experiment 1, the LR images from the QMUL-SurvFace benchmark dataset [24] were conveyed as inputs. The learned residual images were added to their corresponding LR ones. Since the target HR images were not available, we used a different assessment approach. More specifically, we used a face recognition system [30] as an evaluation tool. We provided LR faces images to the recognition system and recorded the performance of the system. Then, we conveyed the learned HR ones and computed the performance of the recognition system. Finally, we compared the two results.

We should mention here that the face recognition system was just used as an assessment tool and that the recognition task is out of the scope of this paper. This implies that the performance of the recognition system was not important but rather the improvement of the performance (if any) between the two considered scenarios. For this purpose, we chose a simple face recognition system proposed in [30]. It extracts the Histogram of oriented gradients (HOG) feature [31] from the faces images. The obtained visual descriptors are classified using the K-nearest neighbors (KNN) [32] with a number of neighbors equal to 1 (K=1). The distance between the HOG features of the faces in the dataset is calculated using the Euclidean distance.

We used 1,355 identities from QMUL-SurvFace dataset [24] for training and testing the recognition system. To match the recognition system requirements, 41 images (the average number of images per identity) for each identity were picked randomly as it requires a fixed number of images. As for the validation technique, leave one out cross-validation was used. The recognition system was tested with the original QMUL-SurvFace dataset images and the enhanced images using the VDSR model trained in experiment 1. Finally, the test results were compared based on the ratio of the correctly recognized face images.

The recognition system was tested with three different scales 2, 3, and 4. Table IV reports the performance of the recognition system with respect to the considered scale factors. Fig. 18 shows the percentage of performance enhancement when using the learned SR images instead of the original LR images. From Fig. 18, we notice that the performance of the recognition system improved when using the enhanced SR images instead of the original LR one. The increase in performance is almost the same for scale factors 2, 3, and 4 (around 45.5%).

TABLE IV. PERFORMANCE OF THE RECOGNITION SYSTEM WHEN USING LR IMAGES, AND WHEN USING SR IMAGES WITH RESPECT TO SCALE FACTORS 2, 3, AND 4

	Ratio of correctly recognized faces	Percentage of performance improvement
LR images	0.359	0
HR images using scale 2	0.523	45.68%
HR images using scale 3	0.522	45.40%
HR images using scale 4	0.523	45.68%

Fig. 18 shows the percentage of performance enhancement when using the learned SR images instead of the original LR images.

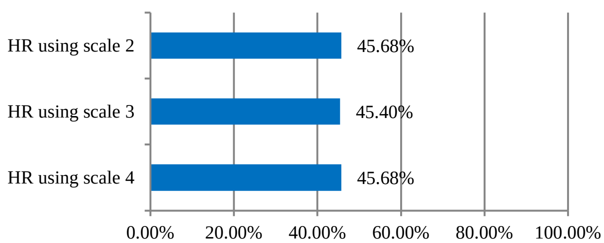


Fig. 18. Percentage of Performance Enhancement when using the Learned SR Images Instead of the Original LR Images with Respect to Scale Factors 2, 3 and 4.

VI. CONCLUSIONS AND FUTURE WORKS

In this paper, we proposed to generate a high-resolution (HR) face image from low-resolution (LR) one for the purpose of person recognition from surveillance camera records. For this purpose, we developed a Deep learning-based SISR system technique that uses Very-Deep Super-Resolution (VDSR) architecture. It is a network with a large number of layers that learns the residual between HR and LR images and accepts images of different scales. The conducted experiments showed that the VDSR model enhanced the face images resolution. In addition, the performance of the recognition system inferred that the proposed VDSR system improves the recognition rate by a ratio of 45.6%.

As future works, we intend to investigate single-scaled models and check the performance of the system with respect to different scales. Moreover, we plan to explore other deep neural network architectures to learn the residual.

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A Method for Predicting Human Walking Patterns using Smartphone's Accelerometer Sensor

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***Abstract*—Recently, the techniques for monitoring and recognizing human walking patterns have become one of the most important research topics, especially in health applications related to fitness and disease progression. This paper aims at combining machine learning techniques with Smartphone sensors readings (i.e. accelerometer sensor) in order to develop a smart model capable of classifying walking patterns into different categories (fast, normal, slow, very slow or very fast) along with variable of gender, male or female and sensor place, waist, hand or leg. In this paper, we use several machine learning algorithms including: Neural Network, KNN, Random forest, and Tree to train and test extracted data from Smartphone sensors. The results indicate that Smartphone sensor can be exploited in developing a reliable model for identifying the human walking patterns based on accelerometer readings. In addition, results show that Random forest is the best performing classifiers with an accuracy of (92.3%) and (91.8%) when applied on waist datasets for both males and females respectively.**

Keywords—Smartphone's; accelerometer sensor; walking patterns; machine learning classifiers

I. INTRODUCTION

With the development of mobile technology over the past few years, mobile devices have become prevalent and nowadays equipped with different kinds of sensors, such as GPS, accelerometer, etc. [1]. The growing development and capabilities of smartphones' sensors have increased researchers' interest to utilize these capabilities in daily life for health care applications that monitor human some activities such as walking patterns for elderly or people with disabilities.

Contemporary Smartphones equipped with many sensors such as Accelerometer, Gyroscope, Magnetometer, and GPS. However, motion sensors are the best suitable for monitoring a device's movements, vibration, tilt, shake, rotation, or swing to identify movements' orientation along the three axes (X, Y, and Z) as shown in Fig. 1. These sensors can determine the phone's orientation if portrait or landscape, and whether the phone' screen is upward or downward. Moreover, the accelerometer sensor can detect how fast your phone is moving in any linear direction [2].

As shown in Fig. 1, when a device is held in its default orientation, X-axis is horizontal and points to the right; Y-axis is vertical and points up; and Z-axis is perpendicular to the face of the screen. Thereof, motion sensors can easily collect the data related to the user's movements and orientations. However, there is a limited ability to automatically support a decision based on large collected data. Therefore, there is a need for developing new data mining and machine learning techniques to make use of these data [2].

Artificial Intelligence provides many solutions based on machine learning techniques that allow the systems to learn and automatically improved according to experiences without explicit programming. Machine learning develops techniques to learn and access through observing to determine the pattern for making a good future decision. Thus, the purpose of machine learning to make the computer automatically decides without any need for human hand [3].

This paper aims at developing a smart model to accurately classify the walking patterns into several categories including: very fast, fast, normal, slow, or very slow based on several machine learning techniques. Therefore, the current study combines general-purpose machine learning techniques with smartphone sensor readings (e.g. acceleration sensor). Also, it involves several sensors that haven't been considered before for recognizing walking patterns (very slow, slow, normal, very fast) and attempts to determine which part of the human body can be the best fit holding smartphone device. And notable and obtain the accuracy according to previous studies related to this algorithm.

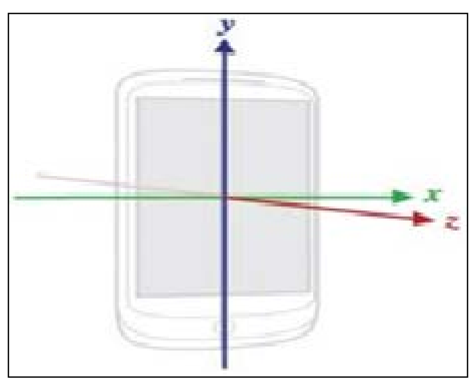


Fig. 1. Device Coordinates System.

II. Related Work

Most of the existing approaches for walking pattern recognition relay on body-worn motion sensors such as accelerometer and gyroscope sensors [4-7]. Different approaches were developed to use foot mounted sensor [8], wearable accelerometer arrays mounted on several parts of the body such as the shank, sacrum, and thigh [5]; and wrist-worn sensors for accurate walking speed estimation [9]. However, these approaches could not efficiently serve general use while having different walking scenarios, in which the user holding his/her smartphone.

Different smartphone-based systems have been developed. Cox et al. developed a simple solution that can estimate the walking speed based on the integration of acceleration by using smartphone and machine learning techniques [10]. Cho et al. suggested to standardize the inertial sensor-based speed estimation using the GPS of the smartphone when the user is walking outdoors [11]. Park et al. investigated the normalized kernel methods on the collected accelerometer data to achieve higher accuracy of walking speed estimation [12].

Even if having an intensive research effort to exploit machine learning techniques to improve the walking speed patterns estimation accuracy, the extracting of effective features still challenging. Thereof, we leverage automated extraction of the most effective features using the deep convolutional neural network (DCNN) to maximize the walking speed estimation accuracy [13, 14].

Recently, deep learning techniques have been dramatically involved in many studies [13, 14, and 15]. However, they focused on the recognition of gait patterns rather than on the recognition of walking speed patterns. Gong et al. (2016) developed DCNN to perform gait assessment for multiple sclerosis patients based on the spectral and temporal associations among sensor data collected with several inertial body sensors [13]. Gadaleta and Rossi adopted the DCNN to recognize a target user based on the way of their walking utilizing the accelerometer and gyroscope data of smartphone [14]. Hannink et al. used the DCNN to estimate the stride length [15].

In this context, the research aims to classify and assess four supervised Machine Learning algorithms, which are Naïve Bayes (NB), KNN and Decision Tree (DT). The study shows the performance accuracy and capability of the experimented algorithms to provide a comparative analysis. Followings summarize the selected supervised algorithms:

- The k-nearest neighbours (KNN): KNN is a simple classification and regression algorithm that stores all the available cases and classifies new incoming cases based on a certain similarity measure. Conceptually, KNN is a simple algorithm; nevertheless, it is still capable of solving complex problems. The KNN algorithm is a type of instance-based learning or lazy learning, wherein the function is approximated only locally. All computation is ceased until classification [16].
- Artificial Neural Networks (ANNs): ANNs are networks inspired by biological neural networks. Neural networks are non-linear classifier which can model complex relationships between the inputs and the outputs. A neural network consists of a collection of processing units called neurons that work together in parallel to produce some output [17]. Each connection between neurons can transmit a signal to other neurons and each neuron calculates its output using the nonlinear function of the sum of all neuron’s inputs [16].
- Decision Tree (DT): DT is a common learning method used in data mining. DT refers to a hierarchal and predictive model which uses the item’s observation as branches to reach the item’s target value in the leaf. DT is a tree with decision nodes, which have more than one branch and leaf nodes, which represent the decision [16].
- Random Forests (RF): RF is a classifier consisting of a collection of tree-structured classifiers. The random forest classifies a new object from an input vector by examining the input vector on each tree in the forest. Each tree casts a unit vote at the input vector by giving a classification. The forest selects the classification having the most votes overall the trees in the forest [18].

III. Methods

This work adopts supervised learning approach to extract features vector that describes the walking patterns of human (fast, very fast, normal, slow, very slow) based on the collected data from fixed and predefined walking distance. Therefore, this paper attempts at determining the best combination of accelerometer sensor data, sensor axis(es) and learning algorithms to detect walking patterns. Fig. 2 defines the research steps.

Based on Fig. 2, the defined method’s steps can be addressed as follows:

Step 1: Collecting raw data by using the accelerometer sensor to be stored in the smartphone file system.

Step 2: Retrieving stored sensor data to an excel file format for pre-processing task. Data will be clustered for each walking pattern attempts according to several variables including: sensor location, type of walk and gender as shown. All variables were coded to their corresponding numeric values as shown in Table I; for instance, values of 1, 0 and 2, which will be expressed as (102), mean that smartphone was placed at the waist of a male user walking normally. Afterwards, the data related to males were separately retrieved from the excel file, as well as the females’ data excluding outliers’ cases.

Step 3: Testing and training of revised data using several machine learning classifiers. In addition, accuracy evaluation applied to assess the performance of the involved classifiers using Orange software, which is an open-source software package released under GPL [19].

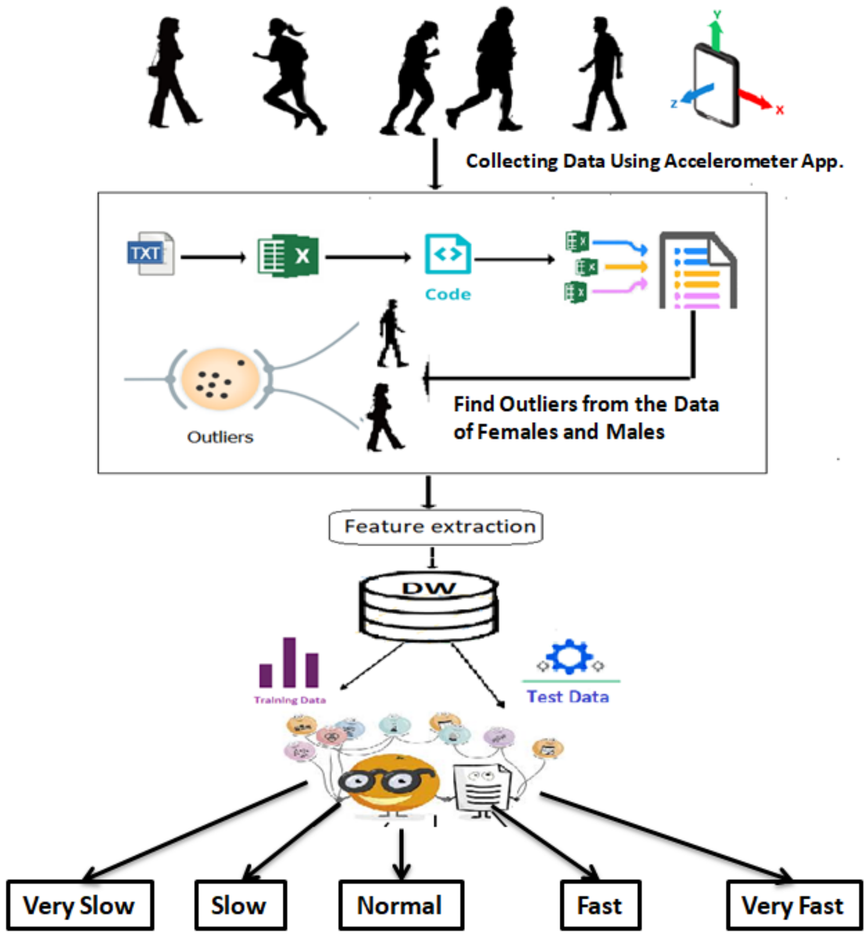


Fig. 2. Research Steps

TABLE I. FLAG MAPPING

Variable	**Option**	**Code**
Smart Phone Position Place	Waist	1
	Hand	2
	Leg	3
Gender	Male	0
	Female	1
Walk Pattern	Fast	1
	Normal	2
	Slow	3
	Very slow	4
	Very fast	5

IV. EVALUATION

To evaluate the proposed model, we compared the accuracy of several machine learning algorithms includes: Artificial Neural Networks (ANN), Random Forest (RF), K-Nearest Neighbors algorithm (KNN), and Tree. These algorithms are commonly used in similar studies due to their ability to process sensing data [15, 51, 20, and 24].

This paper investigates the accuracy evaluation of the used machine learning classifiers for each walk category on the confusion matrix as shown in equation 1, which ranges from 0.0 to 1.0 (Thang et al., 2012). Therefore, the closer of classifier accuracy is to 1.0, the better the prediction of the walks types. Fig. 3 shows the evaluation metric, using Orange software, to ensure the validly of the proposed model of walking patterns (fast, very fast, normal, slow or very slow).

$$Accuracy = \frac{TP+TN}{P+N} \quad (1)$$

Where TP denotes True Positives, TN denotes True Negatives, P denotes positive cases and N denotes Negative cases.

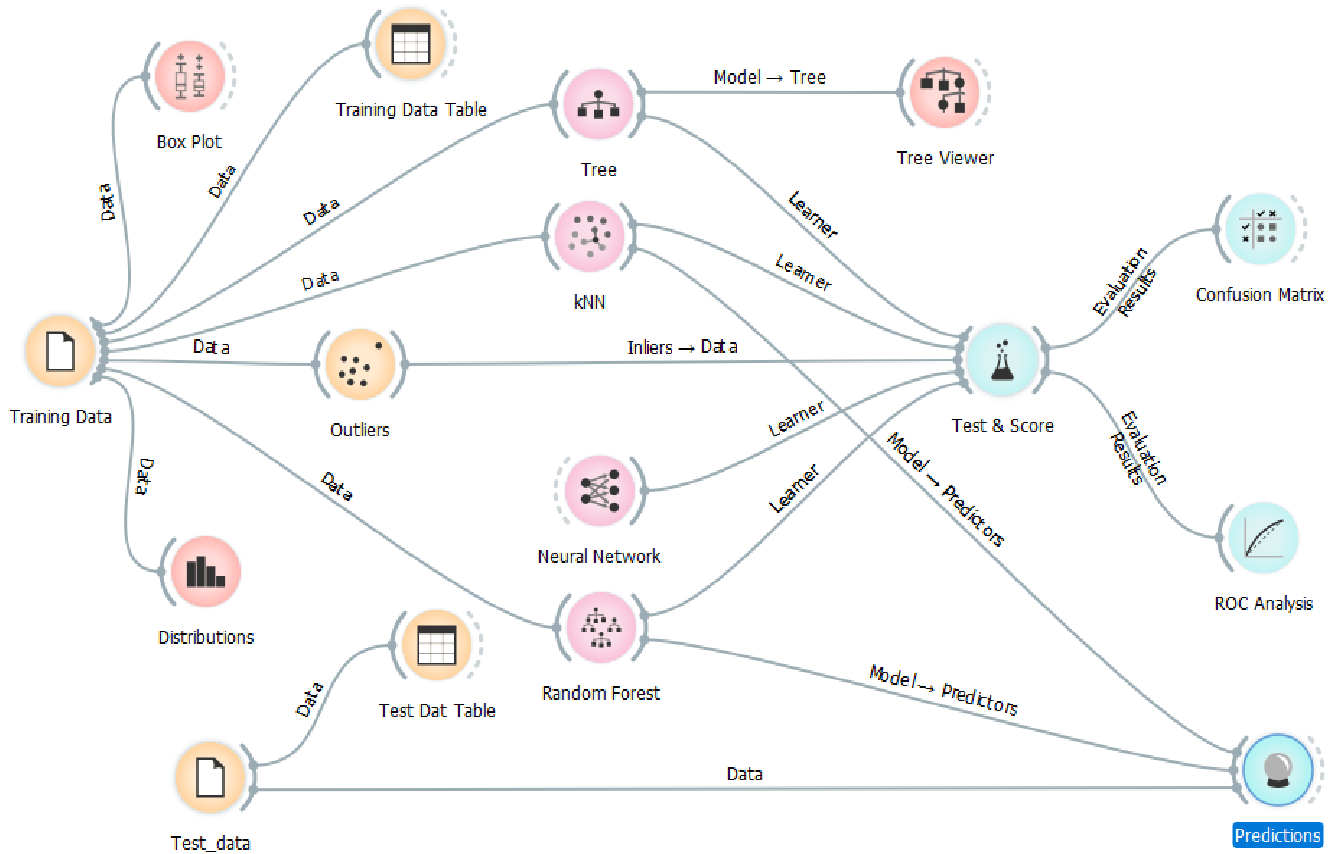


Fig. 3. Evaluation Metric.

V. Data Collection and Experiments

This section shows the real-world experiments conducted to collect the accelerometer sensor data for the walking patterns. In this experiment, a total of eight volunteer university students (four males and four females) with an average age of (21 years) participated for collecting data from smartphone accelerometer of type Huawei; however, different models used (Y6 Prime 2018, Y7 Prime 2018, Nova 3i). Each student asked to walk a certain distance in normal, fast, very fast, slow and very slow speeds in order to collect the data. During the walk, the smartphones placed on the hand, leg, and waist to ensure accurate reading data as shown in Fig. 4.

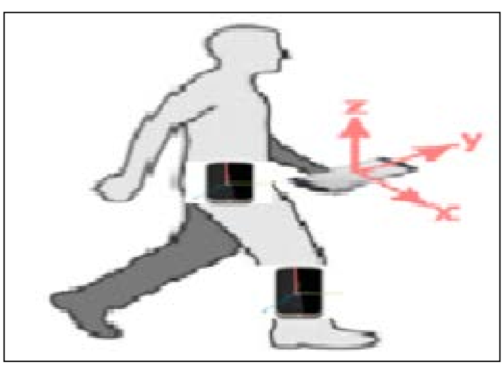


Fig. 4. Sensors Layout.

For proceeding our evaluation procedures, we mapped the codes of the used variables as previously presented in Table I. Then all produced datasets are trained and tested using several machine learning classifiers to evaluate their accuracy including Artificial Neural Networks (ANN), Random Forest (RF), K-Nearest Neighbors algorithm (KNN), and Tree.

VI. Results

As previously described, the resultant dataset from all experiments was trained and tested using several machine learning classifiers. Table II shows a sample of the produced dataset representing the extracted features and variables flags.

TABLE II. Sample of Our Data Set

1	X (m/s)	Y (m/s)	Z (m/s)	Flag
2	-0.755092	-7.313296	0.199615	101
3	-0.058055	-7.719409	-0.482911	101
4	1.220921	-9.970569	0.677047	101
5	3.900410	-12.573337	-1.679872	101
6	0.740468	-15.148089	-0.233811	101
7	-4.812709	-12.647845	-0.614732	101
8	-6.990199	-8.847034	-0.442063	101
9	-3.629466	-10.212100	-1.258363	101
10	1.647435	-15.811786	-1.579438	101

Afterwards, we find and compare the accuracy for each classifier in terms of smartphone replacement; hand; waist or leg. Results prove that the classification accuracy increased when the sensor is placed at the waist. This can be justified as the waist is the steadiest part of the human body when abnormal movements presented. Therefore, the waist readings were approved in this study for validation purpose.

The classification results based on males' waist dataset show that the Random Forest algorithm maintains the highest accuracy level of (92.1%).Similarly, for classifying females' waist dataset, the Random Forest algorithm achieved the highest accuracy level of (91.8%) as well. Table III shows the results.

As shown in Table III, Random Forest is the best performing algorithm when applied to both males and females' waist datasets. However, a very small difference between them, which can be attributed to the different number of trained records and the physiological differences between males and females.

In order to determine the best performing classifier, we separately obtained the confusion matrix of applying all classifiers on waist datasets for males and females to measure their performance. In the confusion matrix, each row represents the instances in an actual class; while each column represents the instance in a predicted class or vice versa. Confusion matrix summarizes the results of the testing algorithm and provides a report of the number of True Positive (TP), False Positives (FP), True Negatives (TN), and False Negatives (FN). Table IV describes the mapped codes for the used variables.

Flags in Table III used to find the confusion matrix as shown in Fig. 5 and 6, respectively.

Based on Fig. 5, results show that the Random Forest is the best performing algorithm when classifying the females' data comes from smartphones placed at their waists. When the walking patterns are fast, it has been found that 889 out of 1414 cases were correctly classified; while when are normal, 2678 out of 3128 cases were correctly classified; and 5063 out of 5368 cases were correctly classified when walks are slow; and 1226 out of 1463 cases were correctly classified when walks are very slow; finally 7674 out of 7717 were correctly classified when walks are very fast.

Similarly, as for the male confusion matrix, results show that the Random Forest is the best performing algorithm when classifying the males' data come from smartphones placed at their waists. When the walking patterns are fast, it has been found that 1066 out of 1586 cases were correctly classified; while when they are normal, 2640 out of 3133 cases were correctly classified; and 4719 out of 5033 cases were correctly classified when walks are slow; and 1438 out of 1781 cases were correctly classified when walks are very slow; finally 9950 out of 10021were correctly classified when walks are very fast.

TABLE III. RESULT OF CLASSIFICATION

Model	**Accuracy Male**			**Accuracy Female**		
	Hand	***Waist***	***Leg***	***Hand***	***Waist***	***Leg***
Random Forest	0.661	0.923	0.615	0.7355	0.918	0.662
Neural Network	0.650	0.913	0.608	0.6833	0.912	0.642
KNN	0.647	0.919	0.594	0.7364	0.915	0.648
Tree	0.620	0.896	0.579	0.7149	0.886	0.605

TABLE IV. CODE DESCRIPTION OF USED DATASET

Flag	**Description**
111	Waist; female; fast
112	Waist; female; normal
113	Waist; female; slow
114	Waist; female; very slow
115	Waist; female; very fast
101	Waist; male; fast
102	Waist; male; normal
103	Waist; male; slow
104	Waist; male; very slow
105	Waist; male; very fast

Predicted

		111	112	113	114	115	∑
Actual	111	853	358	123	80	0	1414
	112	416	2432	258	22	0	3128
	113	142	208	4903	69	46	5368
	114	83	37	83	1166	94	1463
	115	0	2	33	45	7637	7717
	∑	1494	3037	5400	1382	7777	19090

Confusion matrix for Random Forest (showing number of instances)

Predicted

		111	112	113	114	115	∑
Actual	111	779	435	138	62	0	1414
	112	150	2678	282	18	0	3128
	113	78	183	5066	36	5	5368
	114	67	23	97	1160	116	1463
	115	0	0	2	19	7696	7717
	∑	1074	3319	5585	1295	7817	19090

Confusion matrix for kNN (showing number of instances)

Predicted

		111	112	113	114	115	∑
Actual	111	889	349	122	54	0	1414
	112	224	2678	213	13	0	3128
	113	86	189	5063	30	0	5368
	114	62	27	82	1226	66	1463
	115	0	0	10	33	7674	7717
	∑	1261	3243	5490	1356	7740	19090

Predicted

		111	112	113	114	115	∑
Actual	111	888	354	121	51	0	1414
	112	227	2645	245	10	1	3128
	113	106	170	5067	21	4	5368
	114	54	21	113	1185	90	1463
	115	0	0	1	6	7710	7717
	∑	1275	3190	5547	1273	7805	19090

Fig. 5. Confusion Matrix for Females.

Confusion matrix for kNN (showing number of instances)

Predicted

		101	102	103	104	105	∑
Actual	101	1025	343	144	74	0	1586
	102	200	2630	276	23	4	3133
	103	82	108	4760	15	68	5033
	104	109	70	113	1357	132	1781
	105	0	0	17	18	9986	10021
	∑	1416	3151	5310	1487	10190	21554

Confusion matrix for Random Forest (showing number of instances)

Predicted

		101	102	103	104	105	∑
Actual	101	1066	328	125	67	0	1586
	102	219	2640	245	28	1	3133
	103	85	159	4719	29	41	5033
	104	107	58	88	1438	90	1781
	105	0	1	30	40	9950	10021
	∑	1477	3186	5207	1602	10082	21554

Confusion matrix for Neural Network (showing number of instances)

Predicted

		101	102	103	104	105	∑
Actual	101	965	386	165	70	0	1586
	102	186	2561	359	26	1	3133
	103	96	150	4707	27	53	5033
	104	125	52	94	1282	228	1781
	105	0	0	30	46	9945	10021
	∑	1372	3149	5355	1451	10227	21554

Confusion matrix for Tree (showing number of instances)

Predicted

		101	102	103	104	105	∑
Actual	101	1048	308	137	93	0	1586
	102	377	2466	247	41	2	3133
	103	156	239	4469	81	88	5033
	104	117	74	92	1374	124	1781
	105	0	2	79	61	9879	10021
	∑	1698	3089	5024	1650	10093	21554

Fig. 6. Confusion Matrix for Males.

VII. Validation

We validate our model by displaying the Box plot distribution of the Y (m/s2) readings related to males' and females' waist datasets, since these datasets achieved the highest rate of correctly classified cases when applying Random Forest classifier. Results confirmed that there was no significant discrepancy between the mixed data of males and females as shown in Fig. 7, which in turn shows the validity of our experiments.

Furthermore, the model was validated by applying the two most accurate classifiers, Random Forest and KNN on an external Excel file, which contains unflagged data, attributes of the waist; Female; and slow. Results show that the Random Forest algorithm made the correct prediction and returned (113) flag code, which represents waist; Female; and slow respectively as shown in Fig. 8.

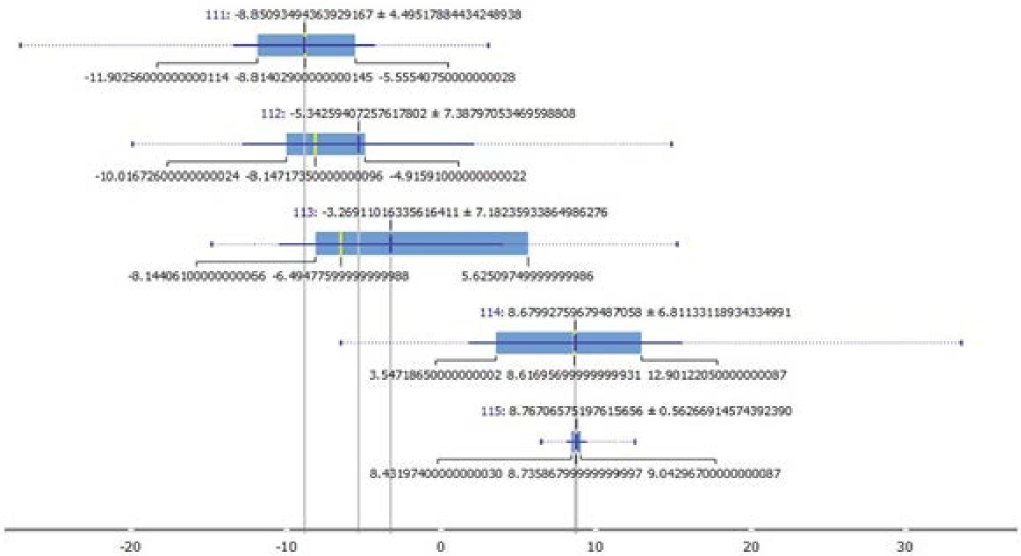
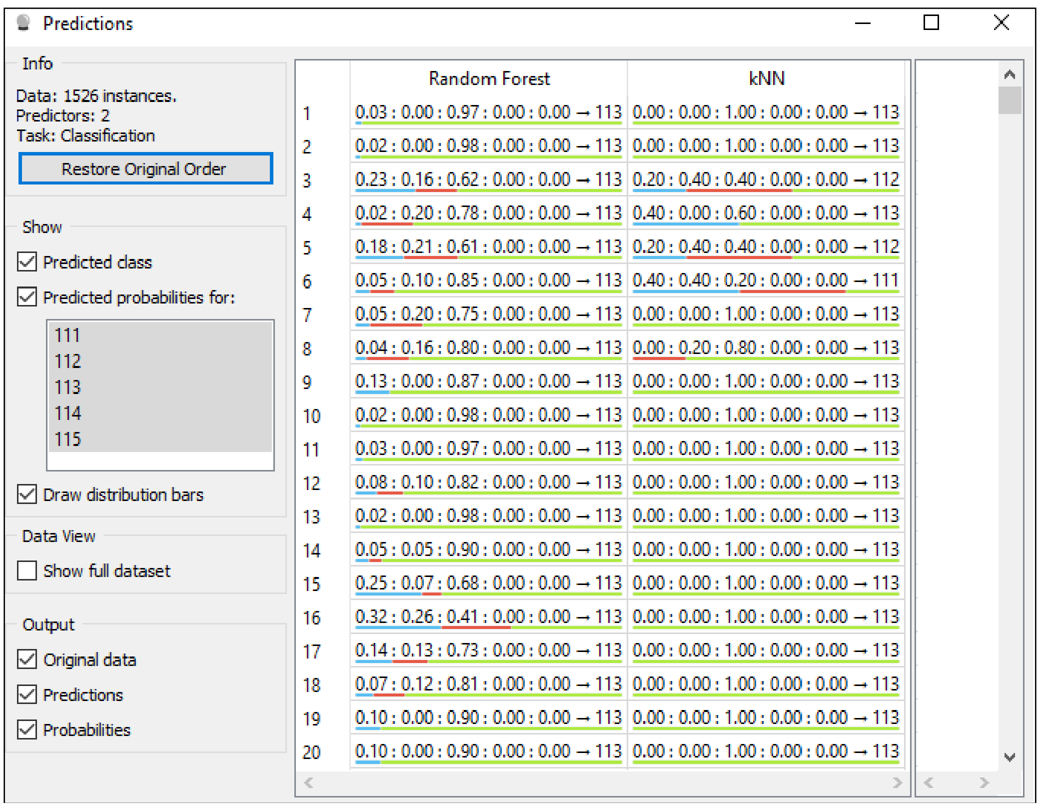


Fig. 7. Box Plot for Attribute ' Y (m/s2).



	Random Forest	kNN
1	0.03 : 0.00 : 0.97 : 0.00 : 0.00 → 113	0.00 : 0.00 : 1.00 : 0.00 : 0.00 → 113
2	0.02 : 0.00 : 0.98 : 0.00 : 0.00 → 113	0.00 : 0.00 : 1.00 : 0.00 : 0.00 → 113
3	0.23 : 0.16 : 0.62 : 0.00 : 0.00 → 113	0.20 : 0.40 : 0.40 : 0.00 : 0.00 → 112
4	0.02 : 0.20 : 0.78 : 0.00 : 0.00 → 113	0.40 : 0.00 : 0.60 : 0.00 : 0.00 → 113
5	0.18 : 0.21 : 0.61 : 0.00 : 0.00 → 113	0.20 : 0.40 : 0.40 : 0.00 : 0.00 → 112
6	0.05 : 0.10 : 0.85 : 0.00 : 0.00 → 113	0.40 : 0.40 : 0.20 : 0.00 : 0.00 → 111
7	0.05 : 0.20 : 0.75 : 0.00 : 0.00 → 113	0.00 : 0.00 : 1.00 : 0.00 : 0.00 → 113
8	0.04 : 0.16 : 0.80 : 0.00 : 0.00 → 113	0.00 : 0.20 : 0.80 : 0.00 : 0.00 → 113
9	0.13 : 0.00 : 0.87 : 0.00 : 0.00 → 113	0.00 : 0.00 : 1.00 : 0.00 : 0.00 → 113
10	0.02 : 0.00 : 0.98 : 0.00 : 0.00 → 113	0.00 : 0.00 : 1.00 : 0.00 : 0.00 → 113
11	0.03 : 0.00 : 0.97 : 0.00 : 0.00 → 113	0.00 : 0.00 : 1.00 : 0.00 : 0.00 → 113
12	0.08 : 0.10 : 0.82 : 0.00 : 0.00 → 113	0.00 : 0.00 : 1.00 : 0.00 : 0.00 → 113
13	0.02 : 0.00 : 0.98 : 0.00 : 0.00 → 113	0.00 : 0.00 : 1.00 : 0.00 : 0.00 → 113
14	0.05 : 0.05 : 0.90 : 0.00 : 0.00 → 113	0.00 : 0.00 : 1.00 : 0.00 : 0.00 → 113
15	0.25 : 0.07 : 0.68 : 0.00 : 0.00 → 113	0.00 : 0.00 : 1.00 : 0.00 : 0.00 → 113
16	0.32 : 0.26 : 0.41 : 0.00 : 0.00 → 113	0.00 : 0.00 : 1.00 : 0.00 : 0.00 → 113
17	0.14 : 0.13 : 0.73 : 0.00 : 0.00 → 113	0.00 : 0.00 : 1.00 : 0.00 : 0.00 → 113
18	0.07 : 0.12 : 0.81 : 0.00 : 0.00 → 113	0.00 : 0.00 : 1.00 : 0.00 : 0.00 → 113
19	0.10 : 0.00 : 0.90 : 0.00 : 0.00 → 113	0.00 : 0.00 : 1.00 : 0.00 : 0.00 → 113
20	0.10 : 0.00 : 0.90 : 0.00 : 0.00 → 113	0.00 : 0.00 : 1.00 : 0.00 : 0.00 → 113

Fig. 8. Result of Test.

VIII. Discussion

In this paper, we proposed a method to accurately predict all patterns of human walking including very slow, slow, normal, very fast. Therefore, it combines general-purpose machine learning techniques with smartphone sensor readings (e.g. acceleration sensor) to develop a smart model capable of classifying and predicting the walking patterns into very fast, fast, normal, slow, or very slow. In addition, it determines the best part for placing the sensor on the human body (Hand, Waist, and Leg). Thus, we provide a distinguished study by using several sensors simultaneously placed at different human body parts to collect sensing data to be trained and tested by accurate classifiers.

To achieve the study aim, we involved several variables including sensor location, gender during the experiments to identify the walking pattern classes as an activity. A total of 8 students, 4 males and 4 females, participated in our experiments and performed different walking scenarios while three smartphones similarly oriented and placed at waist; hand; and leg of every individual simultaneously. The results after processing the involved datasets indicated that the Random Forest (RF) is the best performing classifier in terms of accuracy when classifying both males or female's waist datasets; however, males dataset proves a higher performance with an accuracy of (92.3%) and (91.8%) for females' dataset. In addition, results indicated that the waist can be the best steady human body part for placing smartphone sensors to recognize walking patterns.

Finally, when comparing our work with previous literature, we can find several methods that can be used to determine the walking patterns [1, 21-23]. However, Tang & Phoha (2016) [1] found that KNN is the best which; while our study indicates that Random forest is the best performing classifier. Additionally, Thang & et al. (2012) [22] adopted SVM classifiers to identify the user's gender based on biometric gait with an accuracy of (92.7%). Also, Gupta& et al (2014) [23] conducted a similar study using the Mean shift clustering algorithm with an accuracy level of (95%).

IX. Conclusion and Future Work

In this paper, we developed a method to collect sensing data and accurately classify all human walking patterns including very slow, slow, normal, very fast. The evaluation results of current methods involving the application of four classifiers (K-Nearest Neighbor, Random Forest, Tree, and Neural Networks) indicate that the Random Forest is the best performing classifier. Random Forest achieves a higher accuracy level when applied on waist datasets for both males and females compared to other classifiers. However, the researchers have a plan to improve resultant accuracy and expand the research domain to include more samples of people using different methods and environments settings, such as stairs and rectum.

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Household Overspending Model Amongst B40, M40 and T20 using Classification Algorithm

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***Abstract*—The family economy is a critical indicator of the well-being of a family institution. It can be seen by the total income and how well the household finances is managed. In Malaysia, the household income level is categorized as B40, M40 and T20. These categories can also indicate the poverty level of the household. Overspending is a phenomenon where the monthly expenses are more than the household's total income, which affects economic wellbeing. Finding important factors that affect the spending patterns among the household can reveal the causes of overspending. It will assist the government in mitigating such problems. Availability of 4 million household expenditure records obtained from the survey conducted in 2016 by the Department of Statistics Malaysia eases the aim of this study to develop a household overspending model by using machine learning. The model is developed using 12 household demographic attributes with 14451 household records. The attributes are the number of households, area, state, strata, race, highest certificate, marital status, gender, housing, income, total expenditure, and category as attributes class. The model development employs five machine learning algorithms namely decision tree, Naïve Bayes, Neural network, Support Vector Machines, Nearest Neighbour. The results show that the decision tree through J48 algorithm has produced the easiest rule to be interpreted. The model shows four attributes which were income, state, races and number of households that highly influence the overspending problem. Based on the research finding, it can be concluded that these attributes are essential for improving the indicator measure for Malaysian Family Wellbeing Index in the aspect of overspending.**

Keywords*—*Overspending; classification; poverty; household

I. INTRODUCTION

Malaysian Family wellbeing index consisted of 8 indicators, with the economy being one of it [1]. The wellness of the economy can be measured based on two indicators; income and expense. When a person spends more than his/her income, the phenomenon is called overspending. Overspending is a continuous issue for ages [2][3], which resulted from verities of factors making the issue to be rapidly increased yearly [4]. Overspending may cause by the basic need of a family. However, it also due to lifestyle with the attitude of not being able to self-measure and being critical on the lifestyle. Undeniably, overspending can occur due to an unexpected event that might occur once in a blue month. However, it was not supposed to be happening on a monthly basis.

Overspending is expected to be experienced by most millennials due to the lack of knowledge on how to spend money wisely. With various facilities such as multiple bank accounts, insurance and saving plan causes millennials to easily trapped in overspending. Moreover, with high-cost university fees, youngsters nowadays are facing huge debt even before securing a job. Additionally, unlimited access to online shopping also contributes to this matter. Other than that, using delivery food services causes food expenses to be increased. Bankruptcy is an even more serious consequence of overspending. Forty percent of households in the USA faces with overspending since 1990. The number of non-business bankruptcies in the United States reported being increasing [5]. Malaysian also shows a huge number on this matter. The number is increasing wherein 2018, a total of 303,415 bankruptcies was reported [6].

The phenomenon of over-spending needs to be addressed, as it can lead to social problems due to financial constraints which can result in theft, unauthorized money lending, and long-term personal loans. Limited financial resources, growing of needs and the rising cost of living are challenges that young people face in order to balance their current and future needs. With a variety of financial facilities, especially credit cards, banking, investment, loan and e-wallet, it requires consumers to have the financial knowledge to use the facilities. A variety of basic needs such as emergency care, child education, credit and risk management (insurance/takaful), retirement planning and estate planning with limited resources are a challenge for today's financial management which increases the cost of living as well.

A preliminary study on consumer financial 2016 survey data shows that 8.44% of Malaysians fall into the category of over-spending. However, studies on overspending issues is still limited in Malaysia. Several smart financial management have been taught and used but many of them were focusing on financial management and less focus on the spending style [7]. Various analysis has been conducted on the data, most of the researchers focus on the type of spending [7] and still limited study focus on overspending especially using an artificial intelligent data analytic method to overcome meaningful knowledge. Research on overspending lifestyle has been conducted and found out three main significant factors that influencing spending which was food, housing and transportation. However, the study conducted using regression and not based on the overspending context.

Thus, this study was conducted in order to develop a household over-spending model amongst Malaysians' B40, M40 and T20 using classification techniques. Thus, it will show the overspending pattern among B40, M40 and T20. The model was developed based on the demographic information only as given by the Department of Statistic Malaysia. The contribution of this work beneficial to see the serious factor of overspending issues in a family context. The finding also can be used in finding possible indicators for the multidimensional index in Malaysia.

The rest of this paper is organized as follows: Section 2 presents related work on the overspending data classification. Section 3 presents the material and method used for data classification. Section 4 reports the experimental results and Section 5, concludes the finding.

II. Related Work

Household income management is needed for a wise spending regime. Due to budget constraints, households need to plan and prioritize basic necessities. Basic necessities are defined as daily needs which includes, food, housing, transportation, healthcare and clothing [8]. It was found that low-income households spend most of their income on basic necessities rather than on unnecessary expenses. However, they are still facing overspending.

According to Rashid et al. (2018), based on all income groups and strata, there are three types of household expenditure. First, food and non-alcoholic beverages. Second, housing, water, electricity, gas and other fuels. Third, transportation. These three groups can be classified as basic necessities. Analysis shows that group B40 spends almost two-thirds of their total expenditure on non-alcoholic food and beverages, housing, water, electricity, gas, fuel, and transportation.

In 2019, [9] reported that Malaysian household spends 69.1% in four main groups which include, housing, water, electricity, gas, fuels, non-alcoholic, restaurant and hotel. On the statistical report, the highest contributors to overall consumption were for housing, water, electricity, gas and fuels (24.0%), followed by food and non-alcoholic beverages (18.0%), transportation (13.7%), restaurant and hotels (13.4%).

Rashid et al. (2018) used three regression approach to analyse the relationship between total spending and basic needs among three income group households. Result shows that spending on basic needs has a significant relationship with the total expenditure between-group income. The basic needs of food, transportation and housing showed a significant relationship with total expenditure. In other words, by increasing spending on basic needs will increase household spending. However, the researches still use basic statistical analysis.

Artificial intelligent and data analytic has known as a popular approach where discovering accurate and meaningful knowledge in various domain utilising huge pass data made possible. Its offers various task such as classification, clustering, prediction, diagnostic, and deviation detection [10]. Where, the selection of the methods is depending what kind of business problem and type of data available. The aims are to identify the best model that gives the highest classification accuracy. Besides measure of accuracy, other measure such as mean absolute error, Root Mean Squared Error (RMSE), F-measure, Precision, Recall, the Kappa statistic, ROC and computation time are also considered in evaluating the performance of the model.

Classification usually used for predicting or discovering new knowledge in a form of rules, tree or function [11][12]. There are various algorithms that fall under classification technique such as J48, Naïve Bayes, Neural network, Support Vector Machines and Nearest Neighbour [13]. J48 is an enhancement of the C4.5 decision tree algorithm which functions by creating decision tree that based on data attributes. This algorithm identifies the attribute that discriminates instances most clearly which. The quality of rule, tree or function created from this algorithm can be determined by the accuracy of the model [14]. J48 had been proven to having highest accuracy compared to other algorithm. In analysing poverty level in Indonesia, [15] had done study using J48. Another study done using random forest algorithm in measuring poverty in urban area which provide more directional and timely decision-making assistance for the resource allocation and renewal planning of poor communities [16].

Neural Network is a mathematical model or computational model based on emulation of a biological neural system. There are several neural network algorithms such as ANN, CNN and kNN. The output value of the neuron is usually a non-linear transformation of the sum of stimuli. In more advanced models, the non-linear transformation is adapted by some continuous functions. NN is very popular for prediction with few attributes such as stock market prediction [17], weather forecasting [18] and customer churn [19]. NN was used by [20] in mapping out the poverty in Mexico. Where, CNN was used in predicting poverty mapping for urban areas using imagery for Digital Globe or Planet.

Another algorithm that usually used in study is Bayesian. This algorithm involves statistical methods that assign probabilities or distributions to events or parameters based on experience or best guesses before experimentation and data collection. A Bayes classifier is a simple probabilistic classifier based on applying Bayes' theorem (from Bayesian statistics) with strong (naive) independence assumptions. A more descriptive term for the underlying probability model would be the "independent feature model" [21]. Bayesian has shown as an accurate model for various problem [22][23]. Naïve Bayes was used by [24] in mapping out the potentially poor family in Indonesia to planning the right method in preventing such occurrence towards the family.

Another classification technique that is popular is Support Vector Machine (SVM), which can be employed for both classification and regression purposes. SVM works and completes the analysis through a series of binary assessments on the data. SVM has shown as a good algorithm in the various domain is very popular particularly in image processing.

Thus, this study was conducted in order to develop a household over-spending model amongst Malaysians' B40, M40 and T20 using classification techniques that shows overspending pattern. The model was developed based on the demographic information as given by the Department of Statistic Malaysia (DOSM). The contribution of this work beneficial to see the serious factor of overspending issues in a family context. The finding also can be used in finding possible indicators for the multidimensional index in Malaysia.

III. Material and Methods

The study follows the standard data mining step of three phases which are (1) defining business goal, (2) data collection, (3) data preprocessing and preparation, and (4) development of model [25].

A. Defniing Business Goal

In this study, we define the business goals as to identify the patterns of overspending among various household income classes (B40, M40, and T20). Factors that contributes to the goal will be identified through features selection from source data set.

B. Data Collection

Survey was conducted in 2016 by the Department of Statistics Malaysia (DOSM), with a total of 4 million household expenditure records were obtained. However, only 20 percent of the data were used in this study due to constraints in obtaining all of the data from the DOSM. Data obtained consisted of 12 attributes on demographics data selected. They were number of households, area, state, race, highest certificate, marital status, gender, housing income, total expenditure and category which were described in detail in [26].

C. Preprocessing and Preparation

Phases involve in data preparation were namely attribute selection and class label determination. There were several phases involved in this study which discussed as follows.

The first phase was data preparation. This phase was done by identifying as much as attributes and records can be collected. Then the data cleaning process was done which include generating new attributes of poverty and the overspending category. In his phase, the cleaning process which include replacing incomplete and incorrect data with null was done.

The second phase was descriptive analysis using SQL language. The analysis was done towards the number the percentages and distribution in each state and the total spends for each category. The analysis was then used in overcoming basic knowledge on the overspending pattern amongst B40, M40 and T40.

The third phase was pre-processing by discretising data into the nominal form of attributes. Then, determining the best modelling followed by interpreting the knowledge was conducted.

1) Income class level

a) Generate income class: The income class was generated by referring to the amount of income and state set by the Malaysian government [26]. The algorithm was translated into the rules in Table I.

TABLE I. RULES FOR INCOME CLASS

IF State = ‘Melaka’ OR ‘P.Pinang’ OR ‘Johor’ AND IF income < 4768.92 THEN Category = B40 ELSE IF 4768.92 =<income <9380.15 THEN Category=M40 ELSE Category = T20
IF Negeri = ‘Perlis’ OR ‘Perak’ OR ‘Pahang’ AND IF income < 3461.75 THEN Category = B40 ELSE IF 3461.75=<income <6814.58 THEN Category=M40 ELSE Category = T20
IF State = ‘W.P Putrajaya’ AND IF income < 6814.58 THEN Category = B40 ELSE IF 6814.58=<income <15170.35 THEN Category=M40 ELSE Category = T20
IF State = ‘Sabah’ AND IF income < 3180.85 THEN Category = B40 ELSE IF 3180.85=<income <7622.05 THEN Category=M40 ELSE Category = T20
IF State = ‘W.P Labuan’ AND IF income < 4768.92 THEN Category = B40 ELSE IF 4768.92=<income <12435.15 THEN Category=M40 ELSE Category = T20
IF State = ‘W.P KL’ AND IF income < 6171.85 THEN Category = B40 ELSE IF 6171.85=<income <15170.35 THEN Category=M40 ELSE Category = T20
IF State = ‘Kedah’ AND IF income < 3180.85 THEN Category = B40 ELSE IF 3180.85=<income <9390.15 THEN Category=M40 ELSE Category = T20
IF State = ‘Terengganu’ AND IF income < 4110.00 THEN Category = B40 ELSE IF 4110.00=<income <9390.15 THEN Category=M40 ELSE Category = T20
IF State = ‘Kelantan’ AND IF income < 6814.58 THEN Category = B40 ELSE M40 ELSE Category = T20
IF State = ‘N.Sembilan’ AND IF income < 4110.00 THEN Category = B40 ELSE IF 4110.00=<income <7622.05 THEN Category=M40 ELSE Category = T20
IF State = ‘Selangor’ AND IF income < 5872.65 THEN Category = B40 ELSE IF 5872.65=<income <12435.15 THEN Category=M40 ELSE Category = T20
IF State = ‘Sarawak’ AND IF income < 3461.75 THEN Category = B40 ELSE IF 3461.75=<income <7622.05 THEN Category=M40 ELSE Category = T20

b) Generating class for overspending: The overspending category was divided into two parts which were 0 and 1. 0 implied that the group fall under not overspending category while 1 was for the group whose total expenditure did exceed the total income. The preparation of overspending class was done by using excel software using the following formula:

IF (Revenue - Spend) <0 THEN category overspending = 0

ELSE category overspending = 1

12 attributes as in Table II were ranked using classifier method to obtain influencing factor. As a result, 8 attribute which produced meaningful reading and ranked higher among the rest was obtained with category (0.19), sex (0.05), education (0.05), ethnic (0.03), marriage (0.02), number of a family (0.02), province (0.018) and state (0.018).

2) Discretization: Discretization is a method which converting continuous data into categorical data [27]. For this method, data form three attributes were processed using depth equal frequency method. Table III shows the description of discretized attribute.

D. Model Development

The classification model was developed using the 10 fold-cross validation using application WEKA (Waikato Environment for Knowledge Analysis). 10 experiments were conducted using each five classification models which were J48, Naïve Bayes, Artificial Neural Network, Swarm Vector Machine and k-Nearest Neighbour. Table IV shows a sample of experimental model that has been conducted using kNN with evaluation parameter as Model number, Number of the fold (training: testing), Accuracy, Mean Absolute Error (MAE), Root Mean Squared Error (RMSE), F-measure, Precision, Recall, Kappa statistic, ROC and speed (time taken to build the model). The bold data was best model when compared to all parameters.

The experiment also conducted using other four classification model where the nearest accuracy was form J48 with accuracy of 70%.

TABLE II. ATTRIBUTES DESCRIPTION AND ITS VALUE USED TO DEVELOP THE OVERSPENDING MODEL ON DEMOGRAPHIC

Attributes Name (Variable)	**Type**	**Value**
Household Id (HId)	Integer	1, 2, 3 ,…
Number of members in each household (Members)	Integer	
Province (Province)	Integer	1-Peninsular Malaysia 2-Borneo
State (State)	Integer	1-13: Johor, Malacca, Negeri Sembilan, Selangor,….
Ethnic (Ethnic)	1-4	1-Bumiputera, 2-Chiness, 3- India, 4- Other
Education Certificate (Cert)	Integer	1-Tiada Sijil, 2- ,,,,
Marriage Status (Marriage)		1- Marriage, 2- Single Mother 3- Single Father 4- Single
Sex (Sec)	Integer	1- Male 2- Female 3- other
Total Income (total Income)	Real	
Total Expenses (Expenses)	Real	
Amount Over Spending (Oversp)	Real	
Poverty Category (Category)	String	B40, M40, T20

TABLE III. DESCRIPTION OF ATTRIBUTE DISCRETIZATION

Attributes	**Type**	**Range**
Number of Member each Household	Integer	1- Members< 2.5 2- 2.5<= Members<4.5 3- Members >=4.5
Total Expenses	Integer	1- Expenses < 1690.01 2- 1690.01 < Expenses<3454. 50 3- 3454.50< Expenses < 4800.59 4- 4800.59< Expenses <5367.67 5- 5367.67<Expenses <6557.03 6- 6557.03<Expenses<7297.58 7- 7297.58 Expenses<8924.1 8- 8924.1< Expenses<9875.87 9- 9875.87<Expenses<10597.08 10-10597.08<Expenses<13169.84

TABLE IV. A SAMPLE EXPERIMENT RESULT OF K-NEAREST NEIGHBOUR CLASSIFICATION MODEL

Model	**Fold**	**Accuracy**	**MAE**	**RMSE**	**F-Measure**	**Precision**	**Recall**	**Kappa statistic**	**ROC**	**Speed**
1	2	83.31%	0.1679	0.2982	0.91	0.853	0.833	0.1392	0.697	0
2	3	83.96%	0.1611	0.3013	0.802	0.786	0.84	0.2133	0.696	0
3	4	84.12%	0.1487	0.2874	0.819	0.802	0.841	0.3202	0.789	0.01
4	**5**	**84.77%**	**0.1452**	**0.2834**	**0.821**	**0.811**	**0.848**	**0.3089**	**0.781**	**0.01**
5	6	84.45%	0.1457	0.2855	0.822	0.807	0.844	0.3291	0.788	0
6	7	85.18%	0.1478	0.2852	0.825	0.815	0.852	0.328	0.775	0.01
7	8	83.88%	0.1497	0.2912	0.813	0.796	0.839	0.2843	0.779	0.01
8	9	83.96%	0.1483	0.2881	0.812	0.794	0.84	0.2782	0.762	0.01
9	10	84.53%	0.1471	0.2876	0.823	0.81	0.845	0.3253	0.778	0.01

IV. Analysis Result

A. Overspending Phenomenon

Six descriptive Analyses which is distribution income category based on State, Statistical Analysis of Income, Expenditures and Overspending, Income and Overspending based on income category, distribution expenditures of overspending group by type of spending, and statistical analysis of average types of overspending and income category.

1) Distribution of income category based on state: Income data analysis distribution is performed by making SQL directories of household, state, and class ID variables and importing them to Microsoft Excel. Fig. 1 shows the distribution of the income category by state.

The data shows that the population of Sabah, Sarawak and Selangor are relatively high compared to other states. The Federal Territories of Putrajaya, Labuan and Perlis show the least amount of data.

2) Statistical analysis of income, spending and overspending: Table V shows the results of statistical analysis of income, expenditure and overspending among the B40, M40 and T20 classes. The table also shows the percentage distribution of the number of households analysed in this study. 8.5% of the population fall into overspending, where 42% of the households belonged to the B40, 39% to the M40 while the T20 to only 10%. Out of a total of RM91 million monthly income, RM 54 million was spent each month. However, the study found 1027 households suffering from overspending in B40, while 166 in B40 and 35 in T20, which is about 17,2,1 per cent, respectively. The analysis results also show some of the B40 group is spending more than the M40 and T20. The minimum spends per month for the overpaid is 70 cents especially for students. It can be concluded that 83% B40 lifestyle was able to manage their money very well and very little per cent of M40 and T20 fall into overspending. It is undeniable that the B40 group in Malaysia is very wise to save the money they have as only 17% of the B40 group belongs to those who are overspending. Whereas in the M40, only 2.9% overspending and T20 1.3% overspending. However, these percentage overspending population can cause social problems such as theft, bribe or bankruptcy.

The table shows the maximum overspending amount for B40 is RM 5868. It can be concluded that the amount of RM6000 per household is become significant number avoiding household fall into overspending.

3) Income range and overspending by income class: Further analysis on overspending shows in Table VI. The table shows the B40, M40 and T20 income class populations that fall in the overspending category by income range and spending range.

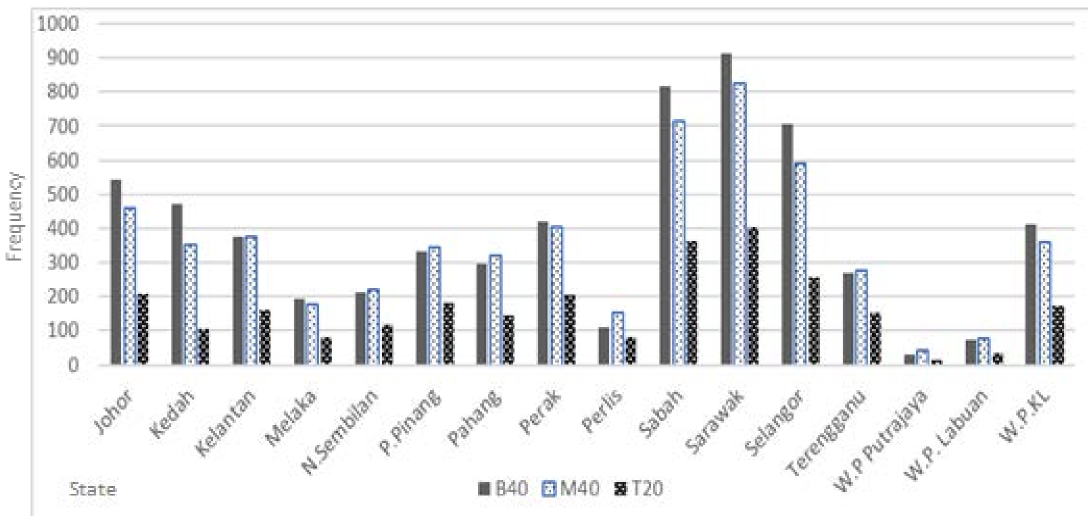

Fig. 1. Frequency of Income Category by State.

TABLE V. Accumulated Amount of Income and Expenditure as Well as Overspending by Income Class

CATEGORY	RESIDENT PERCENTAGE BY CATEGORY		INCOME (RM)	EXPENDITURE (RM)		OVERSPENDING AMOUNT (RM)		EXP>INC
	BIL	(%)		EXPENSE	BALANCE	Min	Max	
B40	6,174	42	18,233,522.61	14,215,885.97	4,017,636.64	0.07	5868.71	**1027**
M40	5,688	39	34,309,736.29	21,353,893.22	12,955,843.07	3.15	10938.27	**166**
T20	2,689	18	38,488,846.37	18,568,726.25	19,920,120.12	92.24	131545.2	**35**
TOTAL	**14,551**	**100**	**91,032,105.27**	**54,138,505.44**	**36,893,599.83**			**1228**

TABLE VI. THE TOTAL EXPENDITURE GROUPS ACCORDING TO THE RANGE OF INCOME AND EXPENDITURE RANGES

Income Range		**Expenditure Range**		**B40**	**M40**	**T20**
0.00	2,768.10	0.00	5,755.01	769 (75%)		
2,768.10	5,197.70			228 (22%)	72 (40%)	
5,197.70	7,627.30			4	4	
0.00	2,768.10	5,755.01	10,981.86	2		
2,768.10	5,197.70			13	29	
5,197.70	7,627.30			19	23	
7,627.30	10,056.90			3	9	12
0.00	2,768.10	10,981.85	16,208.70			
2,768.10	5,197.70			2		
5,197.70	7,627.30				8	
7,627.30	10,056.90			4		
10,056.90	12,486.50					7
12,486.50	14,196.10					3

The table shows the most populous population of the overspending is income below 2,768. 75% of B40 fall this category, while 22% B40 and 40% M40 fall overspending for income more than RM 2,768.1 and less RM 5,197. The range shows that 97% B40 fall into overspending with income less RM 5197.70.

Data also show 39% of M40 fall into overspending for income less RM 5197.70. Its indicators that basic need of living in Malaysia per household should be less than RM 5500 but nice if RM 6,000. However, these findings are not conclusive because there is a need for more in-depth study of the aspects of spending patterns among Malaysians that need to be studied. The analysis results do not describe the type of expenditure allocated that they belong to the overspending group, which fall into the leisure lifestyle.

The data also shows only 3% of B40 fall overspending more than RM 5,5197.7 as we defined as improper financial management. Seven 7 households fall into this category, most of the area family with 2-5 number of members per household, income between RM3K to RM7K, education is SPM and diploma, 2 females and 5 males, and from Johor, Kedah and Selangor. Similarly, data also shows about 60% of M40 fall into overspending in which income more than RM 5,519.7. Most M40 overspending is from Kedah, Sarawak and Perak, their education level mostly SPM/STPM, they are Bumiputera and Chinese. While for T20, most of them area Bumiputera and India, with education level either SPM, certificate or diploma and they are scattered in Malaysia.

B. Classification Experiment Result

As stated earlier, the aims for mining the data is to discover knowledge on overspending pattern using a classification approach. Table VII shows the summary of classification accuracy result for the five classification models. Where, the bold value showed the best result for each classification model. The accuracy shown here is represented the best model obtained at which fold of training vs. testing data. SVM has proven to be the best model for household overspending model amongst B40, M40 and T20 with accuracy of 89.17% followed by J48, ANN, kNN and Bayes with accuracy of 88.84%, 86.97%, 84.77% respectively. Even though SVM shows the best accuracy, J48 classification model was selected for rule generation. This is due to the ability of J48 to presenting the model in the form of rule which make it easier for knowledge discovery.

Tables VIII to X show the overspending rules generated from six types of attributes for B40, M40 and T20 group respectively. The rules were extracted from decision tree developed by J48 algorithm which represent the important in sequence.

From the rules generated, it can be seen that for B40 group that live in Melaka, Perlis, Perak and Sarawak, over spending happened. For B40 that live in Perlis, Federal Territories, Labuan, Penang, Johor and Selangor, overspending happened if expenditure below RM 3952.62. Overspending also happen among B40 if total expenditure is between RM 3952.62 and RM 6557.03 for resident of Johor having fewer or 4 children. In Terengganu, the B40 group said to be overspend with total expenditure of less than RM4800.59. In Malacca, B40 group considered as overspent when their spending reached RM5367.57. Lastly, overspending would happen if B40 lives in rural area of Kedah.

In Perak, Sarawak, Perlis, Labuan and Selangor, M40 who spend more than RM 6557.03 considered as overspent. In Melaka, the M40 overspend when the total expenditure reached RM 5367.67. In Labuan, the M40 overspend when the total expenditure reached RM 10350.4. However, for M40 who lives in Kedah with total expenditure between RM7297 and RM10350.4 they considered to be in overspend category. In Kuala Lumpur and Terengganu, the M40 group overspend when their total expenditure exceeds RM4800, especially for those living in the city. These rues can be seen in Table IX.

Table X shows the overspending rules for T20 group. T20 group considered to be overspent when their total spend exceeds RM 6557.03. The overspending T20 is among those who lives in Negeri Sembilan and Pahang. In Malacca, T20 considered to be overspent when total expenditure exceeded RM9875.87. Lastly, in Labuan, the T20 group is overspent when the total expenditure exceeds RM10350.4.

TABLE VII. COMPARISON ACCURACY RESULT AMONGST FIVE CLASSIFICATION MODEL

Model	**Folds**	**Accuracy %**				
		J48	**ANN**	**Bayes**	**SVM**	**kNN**
1	2	87.30	85.59	83.06	87.95	82.74
2	3	87.87	87.13	83.55	89.09	83.63
3	4	88.03	**86.97**	83.14	88.52	83.06
4	5	88.60	85.83	83.39	88.84	**84.77**
5	6	88.68	86.81	82.74	89.09	84.12
6	7	88.60	86.89	83.39	88.52	84.61
7	8	88.68	86.97	82.98	**89.17**	83.55
8	9	88.60	85.91	83.63	89.09	83.47
9	10	**88.84**	86.56	**83.63**	89.09	83.88
Average Accuracy		88.36	86.52	83.28	88.82	83.76

TABLE VIII. OVERSPENDING FOR B40

No	Rules
1	If Expenses <= RM6557.03 AND State is Kedah AND Strata is Rural
2	If Expenses <= RM4800.59 AND State is Terenggganu
3	If State is Kedah AND Expense between RM7297.59 AND RM10597.08 or more than RM13169.84
4	If Expenses <=RM6557.03 AND State is N. Sebilan AND household members <=4
5	If Expenses <=RM6557.03 AND State is Perlis OR W.P.KL Or W.P.Labuan Or Pulau Pinang OR Johor OR Selangor
6	If Expenses <=RM6557.03 AND State is Sabah and Ethnic is India OR Chinese OR Bumiputra
7	If Expenses >RM6557.03 AND State is W.P.KL AND household memebers <=4
8	If Expenses >RM6557.03 AND State is Johor
9	If Kedah AND Expense >13169.84
10	IF Expenses <=RM5367.67 AND State is Melaka

TABLE IX. OVERSPENDING FOR M40

No	Rules
1	IF Expenses <= RM6557.03AND State is Kelantan OR Perak OR Sarawak OR Pahang
2	IF Expenses <= RM6557.03 AND State is Kedah AND Strata is Urban
3	IF Expenses <= RM6557.03 AND State is N. Sembilan AND Member of Household is >4
4	IF Expenses >RM4800.59 AND State is Terengganu
5	IF Expenses <= RM6557.03 AND State is Sabah AND Ethnic is Others
6	IF Expenses between RM5367.67 and RM6557.03 AND State is Melaka
7	IF Expenses between RM6557.03 and RM9875.87 and State is Sabah
8	IF Expenses > RM6557.03 and State is W.P.KL AND household members >4
9	IF Expenses between RM6557.03 and RM10350.48 AND state is Pulau Pinang
10	IF Expenses between RM6557.03 and RM8924.1 AND State is Terengganu
11	IF Expenses > RM6557.03 AND State is Perak OR Sarawak OR Perlis OR W.P.Labuan OR Selangor
12	IF Expenses between RM7297.58 and 10597.08 AND State is Kedah
13	IF Expenses >RM10597.08 AND State is Kedah

TABLE X. OVERSPENDING FOR T20

No	Rules
1	IF Expenses > RM6557.03 AND state is Kelantan OR Pahang OR N.Sembilan
2	IF Expenses > RM9875.87 AND State is Sabah
3	IF Expenses is >RM10350.48 AND State is Pulau Pinang
4	IF Expenses >RM 8924.1 AND State is Terengganu

V. CONCLUSION

Studies have shown descriptive analysis results and analytical data analysis using the J48 classification method to produce demographic-based and overspending rules based on expenditure type. Descriptive analysis showed the distribution statistics of the B40, M40 and T20 groups by state. Comparative analysis of the two variables can be performed individually to compare or produce specific patterns. Similarly, a descriptive analysis of overspending on expenditure type shows the average distribution of expenditure types for B40, M40 and T20.

There are six attributes that influence most to overspend which are state, race, income, strata, number of households and categories. The rules can determine the exact rule for overspending for each state. The rules show the attractive features of the overspending when the total expenditure is less than or above RM 6557 per state followed by other features such as race, strata and household numbers. For example, in Kuala Lumpur, the M40 group with more than four children is facing overspending with a cost of over RM 6557. With this model, it can help the B40 category not only depend on the amount of income but also need to look at the number of household aspects. The model also proved that the number of household member can be one of the variable in identifying poverty category as B40, M40 or T20.it can be seen that the higher the number of household member, the higher the total expenses. Moreover, ethnic also become one of the overspending factor which only can be applied in Sabah.

This paper has shown how data analytic help in identifying knowledge of attributes that influence the category of poverty based on demography. However, the rules produced were based on the B40, M40 and T20 data which only covering 20 fractions of the actual number of questionnaires conducted by DOSM. The findings may be inaccurate due to the limited amount of data that reflects the actual occupation and population of Malaysians. This study able to show how data science or analytical data in the domain of data mining able to find more detailed knowledge than existing data sources. The results of the descriptive data section and the analysis of the overspending models in B40, M40 and T20 provided clear picture of analytical data capabilities in the pursuit of more detailed knowledge to assist authorities in making decisions or planning strategic plans for income and expenditure management in Malaysia. At the end of this study, factors of income, state, and number of children/members per house hold were found to be among most influence factors in determining Malaysian Family wellbeing index. However, this paper which focusing on demographic data could not assist in identifying lifestyle. Further research focusing on development overspending model based on type of expenses such as total food and transportation are more beneficial to identify the lifestyle. Therefore, study on type of expenses that have highest amount of expenses can be done in the future. This thus can urge these group to minding their expenses in that base so that they would not fall into overspending category.

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A Hybrid Recommender System to Enrollment for Elective Subjects in Engineering Students using Classification Algorithms

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***Abstract*—One of the main problems that engineering university students face is making the correct decision regarding the lines of elective subjects to enroll based on available information (preferences, syllabus, schedules, subject content, possible academic performance, teacher, curriculum, and others). Under these circumstances, this research work seeks to develop a Hybrid Recommender System. For this, a model based on the Content-based approach of all the subjects that has been studied is developed (using Natural Language Processing and the statistical measures Term Frequency and Inverse Term Frequency), giving it appropriate relevance with the grades that the student has achieved. In addition, a model based on a Collaborative Filtering approach is developed, establishing relationships between different students, identifying similar academic behaviors. Thus, the system will recommend to the student in which lines of elective subjects to enroll to obtain better results in the academic field. The given recommendation will be obtained from machine learning models (XGBoost and k-NN) based on the similarity between the contents of each subject with respect to the line of elective subject and based on the academic relationship between all the students. To achieve the objective, data from engineering students between 2011 and 2016 has been analyzed. The results obtained indicate that the recommendations reach a MAP-k of 82.14% and a precision of 91.83%.**

Keywords*—Hybrid; recommender system; academic performance; term frequency; inverse term frequency; natural language processing; k-NN; XGBoost; MAP-k

I. Introduction

Systems Engineering students at National University of San Agustin, follow a curricular mesh of a considerable number of subjects, many of which are requirements of each other, also considering that they have lines of elective subjects from the second semester of the fourth year of university. There are 3 lines of elective subjects:

1) Line A: a) Electronic Business, b) Advanced Topics in Databases, c) Management of Information Systems and Technologies.

2) Line B: a) Introduction to the Development of Entertainment Software, b) Computer Graphics, Computational Vision and Multimedia, c) Development of Software for Games.

3) Line C: a) Introduction to the Development of New Platforms, b) Advanced Development in New Platforms, c) Emerging Platforms.

Of the lines of elective subjects previously described, every student is obliged to follow only two of them. The first subject of each line does not have a requirement to be taken, but the second and third have as a requirement the previous subject of each line of elective subjects.

Students must choose the most convenient lines of elective subjects for them, according to different criteria (interesting subjects according to their preferences, subjects in which their performance is higher, etc.). However, decision-making involves tasks that need time to be analyzed and include activities such as: searching the contents of each subjects of each line of elective subjects, examining carefully the syllabus, requesting access to the curriculum to analyze the content of each subject involved, review the statistics of the subject, or ask for advice from different students who already have the experience of the subject, although the comments may be too subjective depending on the experience.

The decision to choose in which lines of elective subjects to enroll brings with it some restrictions during the university studies. For example, the line chosen must be completed, thus, if the student chooses lines A and B, he must enroll and pass all the subjects on those lines, and otherwise he will not be able to obtain the degree of graduate or bachelor. Another complication is that the student cannot choose the lines again once they have enrolled in one; this means that there is no possibility of changing lines of elective subjects once they have been chosen the first time.

In addition to the previously described restrictions, the disapproval and dropout rate is high compared to other professional schools within the university. Therefore, there is a need for a tool that adequately suggests to the students in which lines of elective subjects they should enroll based on their preferences and performance in all the subjects they have previously studied, and based on the choice of students with academic behavior similar to the student obtaining an objective and exact recommendation; all this making use of the tools and techniques of: 1) a Content-based Recommender System, 2) a Collaborative Filtering Recommender System, and 3) a Hybrid Recommender System, generated from the results of the Content-based Model and the Collaborative Filtering Model.

This research seeks to solve a very common problem among university students by analyzing student performance and analyzing teaching content, tools that are part of Educational Data Mining (EDM) [1] [2] [3] [4] that is focused on the discovery of knowledge that involves education and data mining. EDM can be applied to discover patterns in data sets to automate the decision-making process of teachers, students and educational authorities [5].

The paper has been organized in the following way. Section 2 describes some basic concepts about Recommender Systems. Section 3 gives an overview of works related to Recommender Systems in education, and some using Hybrid Models. Section 4 describes the proposed solution, objectives, architecture, techniques, and methods used in the research. Section 5 details the procedure for developing the Hybrid Recommender System: Content-based model, the Collaborative Filtering model, and the hybridization. Section 6 details the accuracy levels achieved with the Content-based Model, the Collaborative Filtering Model, and the Hybrid Model. Finally, Section 7 describes the conclusions reached in this study, and details some guidelines on future works.

II. Recommender Systems

A. Recommender System

Recommender Systems (RS) are software tools and techniques providing suggestions for items to be of use to a user [6]. In [7], RS are defined as any system that provides individualization of the recommendation results and leads to a process that allows users to build interesting or useful objects in a wide range of possible options in a customized way. RS are specifically targeted at people who lack the professional knowledge or expertise to determine the potentially overwhelming number of alternative products a website has to offer [8].

Clearly, the functionality of RS is similar to the social recommendation and information reduction process, which is useless or uninteresting for the user. The main objective of the RS is to provide support to users in making their decisions (online). In particular, the goal is to provide accessible, high-quality recommendations for a large community of users with common features [9].

The basic RS models work with two types of data [10] [11], which are: 1) the user-item interactions, and appraisals associated with the items provided by the user and other users, such as ratings or buying behavior, and 2) the attribute information and description about the users and items such as text profiles or keywords. Methods which use the former are referred to as methods of Collaborative Filtering, while methods that use the latter are referred to as Content-Based recommender methods. Some RS combine these different aspects to create hybrid systems. Hybrids systems can incorporate the strengths of various types of RS to build approaches than can more robustly perform in a wide variety of settings.

B. Content-based

Content-based Recommender Systems (CBRSs) rely on item and user descriptions (content) to construct item representations and user profiles to suggest items similar to those already liked by a target user in the past. The basic process of producing content-based recommendations is to match the attributes of the target user profile with the attributes of the items in which preferences and interests are stored [6]. The main assumption behind this model is that the behavior of a user remains unchanged over time; hence, the content of past user actions may be used to predict the desired content of future actions [7].

At the most basic level, CBRS relies on two data sources: 1) The first data source is a description of different items in terms of content-centered attributes (for instance, a representation could be the manufacturer's text description of an item), and 2) the second data source is a user profile generated from user feedback about different items [10].

To determine the similarity between items, it is necessary to encode the content of each item, for this the TF-IDF matrix is used. TF (term frequency) describes how often a certain term appears in a document (assuming that important words appear more often). IDF (inverse document frequency) is the measure that is combined with the TF; their goal is to reduce the weight of terms that appear very often in all documents. The idea is that these very frequent terms are not useful to discriminate between documents, so more weight should be given to the words that appear in a few documents. To measure the similarity from the TF-IDF matrix it is necessary to use cosine similarity (1). This metric measures the similarity between two n-dimensional vectors based on the angle between them. The similarity between two items a and b is formally defined as follows:

$$sim(\vec{a},\vec{b}) = \frac{\vec{a}.\vec{b}}{|\vec{a}|*|\vec{b}|} \quad (1)$$

C. Collaborative Filtering

Collaborative Filtering Recommender System (CFRS) is based on the assumption that similar users prefer similar items or that a user expresses similar preferences for similar items [7]. The basic idea of collaborative filtering methods is that these unspecified ratings can be imputed because the observed ratings are often highly correlated across various users and items. Most of the models for collaborative filtering focus on leveraging either inter-item correlations or inter-user correlations for the prediction process [10].

Euclidean distance (2) is the simplest and most common example of measure used to estimate the distance between two points and identify similar users or items, where n is the number of dimensions (attributes) and x_k and y_k are the kth attributes (components) of data objects x and y, respectively.

$$d(x,y) = \sqrt{\sum_{k=1}^{n}(x_k - y_k)^2} \quad (2)$$

CFRS methods are categorized into two general classes, namely model-based and memory-based [7]. Model-based algorithms use the underlying data to learn a probabilistic model, such as a cluster model or a Bayesian network model; subsequently they make predictions using the model. Memory-based methods store and access raw preference information in computer memory to find similar users or items, and make predictions as required. Based on a set of user ratings about items, they seek to induce a model for each user based on a collection of user rating about items that would allow the classification of unseen items into two or more classes, each of which corresponds to specific points in the accepted rating scale.

D. Hybrid Methods

Hybrid methods combine two or more recommendation techniques to achieve better performance and to take out drawbacks of each technique separately [7]. It is notable that these different systems use different input types, which have distinct strengths and weaknesses [10]. Some recommender systems, such as content-based systems, are more effective in cold-start settings where there is no significant amount of data. Other recommender systems, such as collaborative methods, are more effective where there is significant amount of data, Usually, CFRS methods are combined with CBRS methods. According to [1], Hybrid RS could be classified into the following categories: 1) combining separate recommenders, 2) a single unifying recommendation model, 3) adding collaborative features to content-based models, and 4) adding content-based features to collaborative models.

According to [9], there are three base hybridization designs: monolithic, parallelized, and pipelined hybrids. The first design incorporates several recommendation techniques in the implementation of a single algorithm. The parallelized design, needs at least two models that produce recommendations independently, later combined with weighted, mixed, and switching strategies. The third design is when the output of one recommender becomes part of the input of the subsequent one.

III. Related Works

In [12], it is identified as a problem for university students to make the right decision regarding their academic itinerary based on available information (subjects, schedules, classrooms and teachers). This work proposes the use of an RS based on data mining techniques to help students in this type of decision. They worked with real data corresponding to seven years of the School of Systems Engineering of the University of Lima. After four tests an accuracy of 77.3% was achieved. They used the Decision Tree technique, which were created from a school database, to generate rules. Finally, the system generates recommendations based on these rules.

In [13] an Intelligent RS framework was designed that can predict the academic performance of the first year of tertiary education students, thus guiding the management of the educational institution in its decision-making on early intervention strategies. They used data obtained from the student archives of Babcock University, Nigeria. From such students, information was taken related to their family, pre-university educational performance and the result of the university entrance exam. For the study they used Decision Trees and Multilayer Perceptron to generate models; reaching an accuracy of 96.78%. Similarly, in [14], students' background information is used to analyze their performance in the first year of study.

Michael O’Mahony and Barry Smith in [15], have developed an Enrollment RS at the University of Dublin, where students learn 12 modules per year, of which 10 are specific to the area of study; and 2 modules are elective from the broader curriculum. Thus, the authors developed the system based on collaborative filtering and content-based methods. The first suggested elective modules based on past choices of students with similar behavior. The second made use of associated text fields detailing the module description and learning outcomes. After this, it is calculated the similarity between modules and determine which ones would be recommended to the student.

In [16], Vialardi et al. propose an enrollment RS based on the student's academic performance record. The system works with two attributes: a) inherent difficulty of a given course and b) measure of a student's competence for a given course based on grades obtained in similar courses. Different data mining methods were evaluated: C4.5, k-NN, Naïve Bayes, Bagging and Boosting, to achieve the best result for this application domain. They concluded that Bagging is the method that guarantees prediction accuracy.

In [17], AACORN is presented, a case-based system that recommends courses to students at DePaul University. Each student's information is organized based on four characteristics: the student's academic program, the curriculum, the student's general grade point average, and the student's history of courses. The system reuses the past experience of students to infer the appropriate courses that a student can enroll in the next study period. Two students in the same program and with similar interests are likely to take the same courses many times. In this way, a student seeking a recommendation can use the experience of students who have completed the program as if it were a template. Each course found in the template that the student has not taken is probably a good course to enroll in.

In [18] and [19], clustering (k-means) and association rules (a priori algorithm) are used to recommend courses to students in e-learning systems. Besides, it is developed an algorithm that combined both. As a result, it is concluded that the combined model generated more and better rules, which allows recommending different combinations of courses to the student, unlike the association rules model that only generated an association rule for the recommendation.

In [20], a Hybrid Recommender System based on machine learning is proposed to recommend Massive Online Open Courses (MOOC’s). It makes use of implicit evaluations on the courses, to determine the behavior of each student and generate recommendations for users with similar preferences. The system is trained with a descending gradient. The main drawback found is how computationally expensive it is to make recommendations in real time. To solve this problem, the neighborhood concept is proposed, and with it the use of clustering techniques.

In [21], a hybrid multiple criteria RS applied to the recommendation of university courses is presented (information from the University of Cordova during three years) using CBRS and CFRS methods. The proposed model combines student and course information using configurable weightings to determine the relevance of each criterion. In this way, a genetic algorithm has been implemented in which the relevance of each criterion in the recommendations can be controlled, as well as obtaining the best configuration of all the parameters used in the RS.

In [22], an element-based and user-based CFRS methods have been combined with a boosted CBRS method. The hybrid model adds average ratings as content based on collaborative filtering in the last step to make the final recommendation list more relevant to the user. The proposed hybrid algorithm was tested on two real-world datasets: 1) MovieLens dataset, and 2) dataset consisting of student scores at a Turkish university. The model was validated with k-fold cross-validation and a survey among students.

IV. The Proposal

The previously analyzed models use student information (educational and personal background, grade history), but do not give too much importance to the characteristics of the subjects themselves. The closest approach is to work with the inherent difficulty of a given subject [16] or to work with courses content [21]. The proposal is based on the use of characteristics of the subjects. It is difficult to describe a subject as quantitative variables. However, using natural language processing and word vectorization, it is possible to represent words or sentences as a vector of real numbers. In this way, the content of each subject can be represented as nominal values and used as input in a prediction system. Additionally, subjects can be objectively compared based on words/phrases that represent them with other subjects and even with student interests [23].

The main objective of this study is to design a Recommendation System architecture that adequately suggests to students in which lines of elective subjects they should enroll based on the student's profile, the subject's profile and the interactions between them, obtaining an objective and exact recommendation. To achieve this goal, it is necessary: 1) collect and structure the data of students, subjects and enrollments, 2) generate a Collaborative Filtering Recommender System, 3) generate a Content-based Recommender System, 4) generate a Hybrid Recommender System based on the results of the previous models, and 5) validate the accuracy of each generated model.

The proposed system has involved the analysis, design, implementation and validation of a Hybrid Recommender System that will allow student to know what are the most convenient lines of elective subjects for them, so they can follow subjects according to their preferences and in which they could perform better academically.

Fig. 1 shows the sequence of activities to be carried out for the development of the proposal and to achieve the stated objectives. The information of subjects was obtained from the contents that are described in detail in the curriculum (curriculum of 2002, 2013 and 2017). The information of students and enrollment is used to generate the academic performance matrices with the grades obtained in enrollments between 2013 and 2016. A CFRS is developed from the identification of the 10 students with academic performance most similar to the student, and analyze which lines of elective subjects are more convenient (with greater weight to the most similar students) and generate an ordered list of recommended subjects. A CBRS is developed based on identifying the 10 subjects in which it showed higher performance contrasting them with a TF-IDF matrix, generating an ordered list of recommended subjects. A hybrid RS is developed from the lists recommended by the 2 previous systems. Each ranked list is trained in different classification algorithms (Decision Trees, Logistic Regression, k-Nearest Neighbors, Linear Discriminant Analysis, Gaussian Naïve Bayes, Support Vector Classification, and XGBoost) to generate two models: 1) a model to predict the first line of elective subjects, and 2) a model to predict the second line of elective subjects; with both models generate a new recommendation. Each RS (CFRS, CBRS, Hybrid) was validated with the metrics: MAP-k (Mean Average Precision at k), precision and recall. MAP-k is a metric used to validate the precision in RS when the recommendation is treated as a ranked list, where it is rewarded for getting many "correct" or relevant recommendations, and it is rewarded for having them at the top of the list (better ranking).

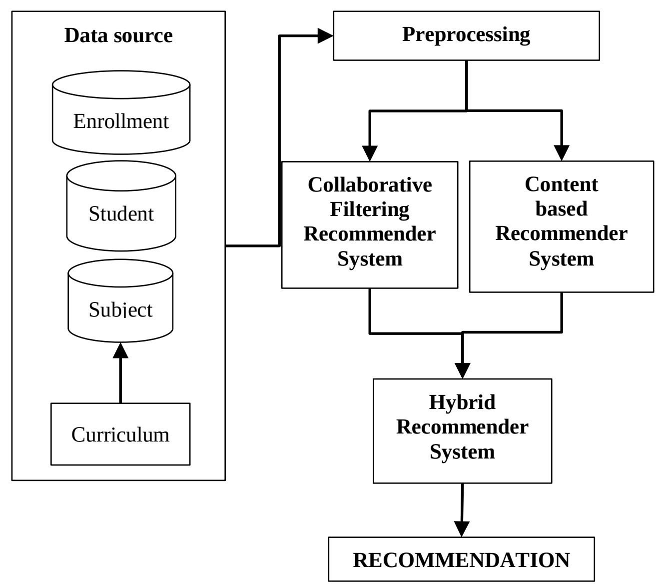

Fig. 1. Activities for the Development of the Proposed Hybrid Recommnder System.

V. Implementation of Proposed Model

For the development of the proposal, the Python programming language is used, together with the Jupyter development environment [24]. Additionally, it was necessary to incorporate the Python libraries: pandas, numpy, tika, pickle, sklearn, scipy, spacy, xgboost.

The enrollment (including grades), subject and student’s data was stored in an .mdb file. Likewise, the content of the subjects was obtained from the curriculum, specifically in the section that gathers all the contents.

A. Collaborative Filtering Recommender System

To adequately represent the academic performance achieved by the student, it is necessary to normalize their grade. For this, the min-max normalization (3) is used, within each class (set of students who share the same subject, group, academic term, and year). Thus, the normalized grade represents adequately the performance within a specific class. For example, if the student has a grade of 16, while the maximum grade for the class is 18 and the minimum grade is 8, then the normalized grade is 0.6.

$$x' = \frac{x - \min(x)}{\max(x) - \min(x)} \quad (3)$$

Later, a table is generated from the record of each student's grades. Each column of the new table represents each one of the subjects present in the curriculum of 2002 and 2013 (102 columns), and each row indicates the normalized grade that each student has obtained in each of those subjects (935 rows).

To identify which students have similar academic performance, the Euclidean distance (2) between each row is calculated. For the recommendation, the 10 most similar students to the target student are identified. From this, the elective subjects that these 10 students have chosen are identified, generating a weighted ordered list of lines of elective subjects that are going to be recommended to the target student.

B. Content-based Recommender System

To generate a CBRS it is essential to have coded information on each subject. For this, the contents of each subject stored in the curriculum are used. Analyzing these texts involves lemmatization or stemming processes. Stemming and lemmatization are techniques of Text Normalization, indispensable to process the content of each subject. Stemming is a process used in removing derivational suffixes as well as inflections so that word variants can be conflated into the same roots (the roots do not have to be words of a language). On the other hand, lemmatization uses vocabulary and morphological analysis of word and tries to remove inflectional endings, thereby returning words to their dictionary form. In [25] y [26], they have compared both techniques and agree that in comparison with stemming, lemmatization produced higher precision. Consequently, this paper uses the lemmatization technique.

During the lemmatization process, the spacy library is used to lemmatize the content of each subject. It is also necessary to convert the text to lowercase, and conjunctions, prepositions, punctuation marks, stop words are eliminated (a text normalization technique, which uses vocabulary and morphological analysis of word and tries to remove inflectional endings, thus returning words to their dictionary form). With the lemmatized content of each subject, and using the TfidfVectorizer object [27] from the sklearn library, a vocabulary of features common to all documents is generated (vocabulary with 100 words), and most importantly, a matrix of TF-IDF features. The documents are encoded by TF-IDF matrix as vectors in a Euclidean space, where the dimensions of the space correspond to the features that appear in the vocabulary.

Once the TF-IDF matrix has been created, the next step is to identify the subjects in which the student has obtained the best performance; this is measured with the normalized grade. The 10 best-valued subjects are analyzed from the lemmatize content, and attached to the TF-IDF matrix. The new record is represented as a vector in the TF-IDF matrix and represents the student profile. The cosine similarity (1) is used to identify which elective subjects are the most similar to the student profile. Thus, a weighted ordered list of recommended lines of elective subjects is generated and recommended to the student.

C. Hybrid Recommender System

The previous systems generate a weighted list of lines of elective subjects according to academic behavior similar to other students (CFRS) and academic performance according to personal preferences (CBRS). Both are weighted lists that reflect the relevance of each line, choosing the two lines with the greatest relevance.

The Hybrid RS takes the weights for each line as input to various classification algorithms that will predict which lines of elective subjects to recommend. Two models are created for each algorithm: 1) a model to predict the most relevant line of elective subjects as a first option and 2) a second model to predict the second line of elective subjects as a second option; remembering that students have to choose two lines of elective subjects from the three offered by the university.

The classification algorithms used are as follows: Logistic Regression, Decision Trees, k-Nearest Neighbors (k-NN), Linear Discriminant Analysis, Gaussian Naïve Bayes, Support Vector Classification from Support Vector Machine (SVM), and XGBoost. For modeling, the dataset was divided into training data and testing data (30% for the first model, and 25% for the second model, thus avoiding overfitting). In Table I it can be seen that the first model to predict the first option, achieves better predictions (60% precision in testing data) with the algorithm XGBoost and Logistic Regression. While Table II shows the precision in the second model (to predict the second option) that it achieves better predictions (77% precision in testing data) with the k-NN algorithm. Therefore, the Hybrid RS uses the XGBoost algorithm (better performance and greater adaptability to different datasets compared to Logistic Regression) to recommend the first option of line of elective subjects, while the k-NN algorithm will recommend the second option.

TABLE I. PRECISION IN CLASSIFICATION ALGORITHMS TO OPTION 1

	Algorithm Precision	
Algorithm	***Training***	***Testing***
Logistic Regression	0.82	0.60
Decision Trees	1.00	0.47
k-Nearest Neighbors	0.62	0.40
Linear Discriminant Analysis	0.76	0.47
Gaussian Naive Bayes	0.74	0.40
Support Vector Classification	0.44	0.40
XGBoost	1.00	0.60

TABLE II. PRECISION IN CLASSIFICATION ALGORITHMS TO OPTION 2

	Algorithm Precision	
Algorithm	***Training***	***Testing***
Logistic Regression	0.67	0.69
Decision Trees	1.00	0.54
k-Nearest Neighbors	0.69	0.77
Linear Discriminant Analysis	0.61	0.62
Gaussian Naive Bayes	0.67	0.54
Support Vector Classification	0.61	0.54
XGBoost	1.00	0.62

VI. RESULTS

Throughout the study, three Recommender Systems have been developed: a Collaborative Filtering Recommender System, a Content-based Recommender System, and a Hybrid Recommender System. The results of each of them are summarized in Table III. The precision in CFRS is 54% and in CBRS it is 63%, however, in the Hybrid RS, based on the output of the other two systems, the precision reached 91%, the 68 and 70% improved the precision of the CBRS and CFRS, respectively. Furthermore, using the MAP-k metric that takes into account the ranked position of the recommendation, CFRS reached 35%; CBRS, 55%; and the Hybrid RS, 82%. Again, the Hybrid RS obtained more accurate results (improved by 130% over CFRS, and 47% over CBRS). Finally, the proposed system reaches the following metrics: the precision is equal to 0.91, recall is 0.83, and F1 is 0.87.

TABLE III. RESULTS IN PROPOSED RECOMMENDER SYSTEMS

	Recommender System Precision	
Algorithm	***Precision***	***MAP-k***
Collaborative Filtering Recommender System	0.540	0.352
Content-based Recommender System	0.632	0.556
Hybrid Recommender System	0.918	0.821

VII. CONCLUSIONS AND FUTURE WORKS

The study developed a CFRS (using a student-subject matrix with the grade obtained), a CBRS (using a TF-IDF matrix and generation of a student profile) and a Hybrid RS (using a classification algorithm with the results of CFRS and CBRS as input). The precision level achieved by the first two models was regular, while after hybridization, the results improved considerably. In this way it was proven that hybrid models take the advantages of CRFS and CBRS, and overcome the disadvantages of them by working individually. Thus, the recommendation of lines of elective subjects to choose during enrollment, reflects adequately the relationship between students, subjects, academic performance and student preferences. Therefore, the recommendations generated by the proposal support objectively the students' decision during the enrollment.

Given that the levels of precision reached by the Content-based Recommender System are greater than the Collaborative Filtering Recommender System, it can be suggested that the attitude of the students towards a given course (student preferences) is highly relevant when recommending a line of elective subjects.

Despite the fact that all the developed models do not take the time as a relevant variable in the design or validation, it is important to update the input data of each model, to regenerate the models guaranteeing their validity. It would have positive effects adding behavioral information of the students in the face of the subjects (attendance, partial exams, assignments, etc.) in addition to the final grade in the subject.

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Method for Automatically Processing Outliers of a Quantitative Variable

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***Abstract*—In data analysis processes, the treatment of outliers in quantitative variables is very critical as it affects the quality of the conclusions. However, despite the existence of very good tools for detecting outliers, dealing with them is not always straightforward. Indeed, statisticians recommend modeling the process underlying outliers to identify the best way to deal with them. In the context of Data Science and Machine Learning, the identification of processes that generate outliers remains problematic because this work requires a visual human interpretation of certain statistical tools. The techniques proposed so far, are systematic imputations by a central tendency characteristic, usually the arithmetic mean or median. Although adapted to the framework of Data Science and Machine Learning, these different approaches cause a fundamental problem, that of modifying the distribution of the initial data. The purpose of our paper is to propose an algorithm that allows the automatic processing of outliers by a software while preserving the distributional structure of the treated variable, whatever the law of probability is. The method is based on the moustache box theory developed by John Tukey. The procedure is tested with existing real data. All treatments are performed with the R programming language.**

***Keywords*—Outliers; boxplot; exploratory data analysis; Programming R; data science**

I. Introduction

Today, with the evolution of information collection techniques and their processing by means of computer tools, the problem of outliers has taken on a significant proportion in data analysis processes [1]. According to the definition of Grubbs (1969), "An outside observation, or 'outlier', is an observation that appears to deviate markedly from other members of the sample in which it occurs" [2]. Their treatment is a crucial problem when analysing the data. Their presence can lead to biased estimates of population parameters and erroneous results, especially in the implementation of statistical tests [3]. Ensuring high quality results when analyzing quantitative data involves detecting outliers and then processing them [4].

Several tools can be used to indicate the presence of these atypical values. Some are based on graphical techniques and others on statistical tests [5]. In those analysis, the quality of the data is one of the determining factors that contribute to a conclusion of a value. However, the methods and techniques used to process the values still do not comply with the methodology indicated by the rules of statistics. Ruilin REN in [6] notes this fact when using imputation methods, developed for missing values problems, to deal with outliers; this would be tantamount to treating outliers as missing data. Whereas statistically, the missing value problem and the outlier problem are different in nature.

It should be noted that the issue of detecting outliers through efficient procedures is solved and is even integrated in most statistical software. However, the treatment of outliers is still problematic because the methods are only diverse, but their effects on the structure of the variables are not taken into account. Among these methods, the best known are the arithmetic mean imputation method and the k-nearest neighbor algorithm, which do not have clear rules for optimal use.

Our work is aimed to automatically deal with outliers in a quantitative variable by minimizing perturbations in the probability law. We propose the determination and processing of outliers by a software in an automatic way without any human intervention. The proposed method consists of exploiting the boxplot, the main tool for outlier detection, proposed by John Tukey. The basic idea is to subdivide the data distribution into several intervals from which surrogate values to be used to replace outliers will be randomly drawn. It is thus a non-monotonic version of imputation techniques in which outliers are not replaced by a single value, but different values, all of them randomly drawn within a specific interval. The determination of the imputation interval is carried out in such a way that it retains the original distributional structure of the data.

In the paper, we first present methods that allow the detection and treatment of outliers. Then, we expose our method as well as the results obtained from the simulations performed on real data.

II. Outlier Detection

An outlier is a data item that deviates significantly from the rest of the data, as if it had been generated by a different mechanism [7]. Barnett and Lewis (1994), define an outlier in a data set as an observation (or set of observations) that appears to be inconsistent with the rest of the data [8]. In other words, an outlier occurs when one of the observations in a data set is inconsistent with the other observations.

Outlier detection is one of the key pillars of data mining technology [9]. Many graphical methods are available to detect the presence of these outliers. These include the moustache box, bar graph, quantum diagrams, histogram, run sequence plot, etc. [1],[10],[11]. In the field of Artificial Learning, the presence of outliers in training databases is a problem for the development of good predictive models for many algorithms. Indeed, they not only make the learning time longer but they also make the obtained predictive model less optimal.

From a practical point of view, outliers may not be errors in some cases. They may be indicative of extraordinary or exceptional situations such as fraudulent behavior, rare events, etc. [12].

III. Treatment of Outliers

Dealing with outliers is a complex task in data analysis. This activity is very often neglected or neglected by analysts precisely because of its complexity or lack of knowledge of its effects on analytical results. An outlier can lead to completely wrong analytical results if it is not properly handled [5]. The detection and subsequent treatment of atypical individuals is a crucial preliminary step in data analysis [3].

These values can be, after their identification, either deleted or corrected [4]. If an atypical value is deleted, an explanation must justify the decision [13], [14]. However, this objective must take into account their origin (random or determined outliers). In the case where the emphasis is placed on the inferential characteristics of a model, during the analysis, the objective is the treatment of the atypical values in order to minimize their negative impact on the parameter estimates and the results of the analysis. In this situation, it is necessary to use appropriate methods for their treatment. This is our case in this article.

There are two main ways of dealing with outliers. The first is to correct them if the sources for producing these data are available. The second is to make a correction for them using an imputation method (by the mean or median method in general).

IV. Proposed Method of Treatment

A. Exploitation of the Boxplot

Most of the algorithms implemented in software for outlier processing use the method of imputation by the positional parameters arithmetic mean and median. This technique has the advantage of simplicity, but in most cases, it greatly alters the distributional structure of the data. Indeed, it remains acceptable when the distribution of the variable is close in practice. The principle of our method is to replace each outlier in the distribution by another value very close to it. However, these imputation values are subject to constraints that eliminate some potential candidates:

a) If the outlier is among the smallest values of the variable, it may not be replaced by a value higher than the mean value of the 1st quartile and the 3rd quartile. In its treatment, preference will be given to values closest to the lower bound of the boxplot (left side of the box).

b) If the outlier is among the largest values of the variable, it may not be replaced by a value lower than the mean value of the 1st quartile and the 3rd quartile. In its treatment, preference will be given to values closest to the upper bound of the moustache box (right side of the box).

c) The imputation values should be drawn within a close range of these values without necessarily being the same for all outliers. This last constraint prevents the cumulation of modality for a large number of outliers, which is one of the sources of distortion of the distribution of the series under study.

To do this, we will exploit John Tukey's moustache box [15]. The latter will be divided into several intervals taking into account the indicators that are the first quartile Q_1, the third quartile Q_3 and the median M_e (see Fig. 1).

Q_1 , Q_3 : are respectively the first and third quartile.

M_e : the median of the distribution.

$IQ = Q_3 - Q_1$: This is the interquartile range.

I_i represents the *i*th interval of the moustache box (i ranging from 1 to 10).

B. Description of the Method

The objective of our method is to automatically process outliers detected with the boxplot. This involves substituting them with another value so as to obtain reliable knowledge from the data, i.e. one that reflects reality. To do this, the boxplot will be decomposed into several intervals (10 in total) of 0.5*IQ length.

The different terminals are a function of the distribution parameters which are the quartiles (Q_1, M_e, Q_3). The use of quartiles is justified by the fact that they are insensitive to outliers. They are robust to the presence of outliers, unlike the mean. This, in fact, will make a real difference.

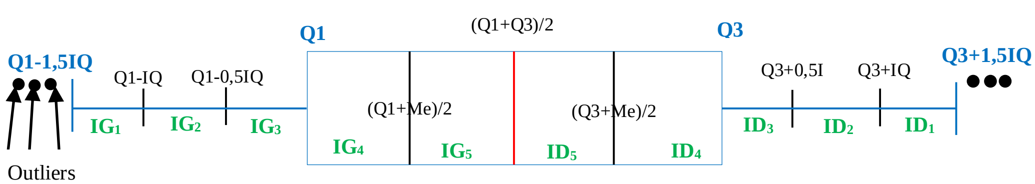

Fig. 1. Boxplot with Interval Decomposition.

To understand the principle of our method, let us consider a group of atypical individuals with respect to a given quantitative variable. Let us assume that the outliers corresponding to these individuals are located on the left side of the box (left moustache); in this case, the algorithm will find replacement values for them by traversing the calculated intervals from left to right. These new values will be randomly drawn from the current interval under consideration. This choice will first be made in interval I1. If, after replacement, it is found that there are new outliers, then this interval is abandoned in favor of the next interval (I_2). This process will be repeated until an interval provides replacement values that eliminates all outliers. It should be noted that in the course of this process, terminal value $(Q_1 + Q_3)/2$, which represents the middle of the box, will not be crossed when randomly selecting new values for all outliers on the left side of the box.

This same process will be done with the atypical individuals located on the right side of the box. At the end of the execution of our algorithm, all outliers will be processed.

V. Proposed Algorithm for Automatic Outlier Processing

1) *Input: quantitative variable X= (x1, x2,...,xn)*
2) *Calculate the median of X*
3) *Calculate the first quartile Q1 of X*
4) *Calculate the third quantile Q3 of X*
5) *Calculate the interquartile range IQ = (Q3 - Q1)*
6) *Determine the limits of the left moustache intervals.*
    - a) *binf = Q1 - 1.5 IQ*
    - b) *minf = Q1 - 1IQ*
    - c) *finf = Q1 - 0.5IQ*
7) *Determine the box terminals*
    - a) *MQ1 = (Q1+Me) / 2*
    - b) *MQQ = (Q1+Q3) / 2*
    - c) *QM3 = (Q3+Me) / 2*
8) *Determine the limits of the intervals of the right moustache.*
    - a) *fsup = (Q3 + 0.5*IQ)*
    - b) *msup = (Q3 + 1.0*IQ)*
    - c) *bsup = (Q3 + 1.5*IQ)*
9) *Determine the intervals at which the left-hand imputation values are drawn*
    - a) *IG1 = [binf, minf]*
    - b) *IG2 = [minf, finf]*
    - c) *IG3 = [finf, Q1]*Tapez une équation ici.
    - d) *IG4 = [Q1, MQ1]*
    - e) *IG5 = [MQ1, MQQQ]*
10) *Determine the draw intervals for the right-hand imputation values*
    - a) *ID1 = [msup, bsup]*
    - b) *ID2 = [fsup, msup]*
    - c) *ID3 = [Q3, fsup]*
    - d) *ID4 = [MQ3, Q3]*
    - e) *ID5 = [MQQQ, MQ3]*
11) *For each left outlier (less than binf) :*
    - a) *For i ranging from 1 to 5 :*
        - i) *Drawing a random value in IGi*
        - ii) *Replace the outlier with a randomly drawn outlier*
    - b) *If there are still left outliers :*
        - i) *Take i = i+1*
        - ii) *Go to a)*

      Else go to 12)
12) *For each right outlier (greater than bsup)*
    - a) *For i ranging from 1 to 5 :*
        - i) *Drawing a random value in Idi*
        - ii) *Replace the outlier with a randomly drawn outlier*
    - b) *If there are still left outliers :*
        - i) *Take i = i+1*
        - ii) *Go to a)*

      Else go to 13)
13) *End of treatment*

VI. Simulations and Results with Real Data

The outlier treatment method we proposed has been implemented under R. It is a programming language for statistics and data science [16].

A. Test with Data Iris from R

1) Description of the database: For the first simulation, we performed the test with the Iris dataset contained in the R environment. This database contains data on 150 iris flowers. For each iris, the length and width of the petals as well as the length and width of the sepals were measured. For this first test of our method, we limit ourselves to the *Sepal.Width* variable (variable measuring the width of the sepals).

2) Simulation and results: First, we plot the moustache box of the variable Sepal.Width with the plot function of R (Fig. 2), i.e. without intervention of our method. We can notice on Fig. 2 the presence of atypical individuals on both sides of the box mustaches (outliers).

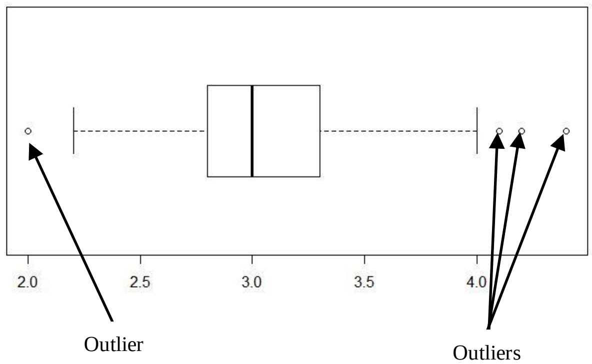

Fig. 2. Drawing of the Mustache Box of the Variable Sepal.Width of Iris with the Original Data.

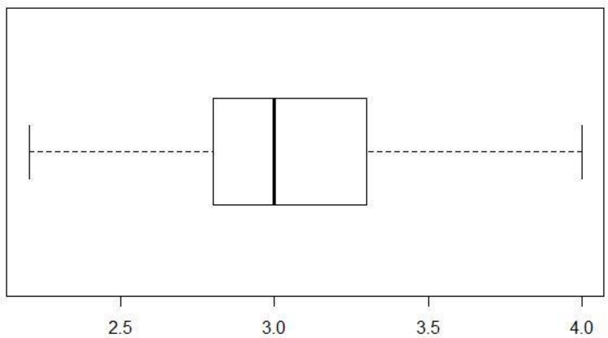

Fig. 3. Drawing of the Sepal.width Variable Moustache Box after Application of the Algorithm.

In the second phase, we apply our outlier processing algorithm to the same data. The algorithm with its execution principle explained above (in 3) will replace these outliers by new ones. We have on Fig. 3 the result obtained with our method.

We can notice that after applying our algorithm on the data, the outliers have been treated so they no longer appear on the moustache box plot.

B. Test with Data from Open Data

1) Description of the database: For the second test, we used data transcribing the monthly performance of the hotel sector in the Brussels region as a resource [17]. This file contains information on the variables *Occupancy.rate* (Room occupancy rate), *Average.Price* (Average price per room) and RevPAR (Income per available room).

2) Simulation and results: First, we plot the moustache box of the variable *Occupancy.rate* with the plot function of R (Fig. 4), i.e. without intervention of our method. We can notice on Fig. 4, the presence of atypical individuals on the left side of the boxplot.

In the second phase, we apply our outlier processing algorithm to the same data. On Fig. 5, we have the result obtained with our method.

One can notice the presence of outliers on the side of the left moustache of the box.

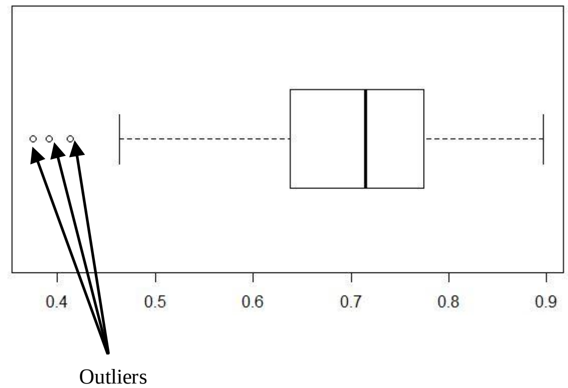

Fig. 4. Plotting the Mustache Box of the Variable Occupancy.rate with the Original Data.

Fig. 5 shows the absence of outliers after application of our algorithm on the data. All the outliers have been processed.

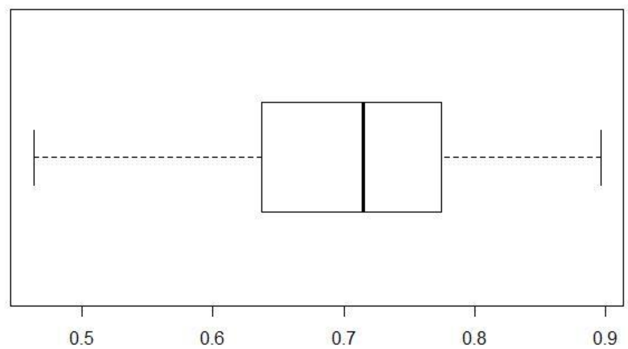

Fig. 5. Drawing of the Boxplot on the Variable Occupancy.rate after Application of the Algorithm.

VII. Conclusion

The algorithm developed by us in this article is mainly based on the principle of John Tukey's boxplot. It exploits its properties to automatically handle outliers in quantitative variables. While the statistical approaches used to identify outliers are effective, current methods of dealing with these outliers are based on imputation techniques that change the probability distribution of the variable of interest. Our method has the particularity of preserving the structure of the distribution of the treated variable. Simulations have shown that the method always manages to treat correctly atypical individuals. This algorithm is part of the more general search for solutions to automate the process of quantitative variables analysis. It will make it possible to automate correct data analysis methodologies with a view of making as reliable as possible the results of data analysis by a machine without human intervention. Another interest of our approach is to be able to write statistical software for novice statisticians that can produce highly reliable results by minimizing the possibilities of common analytical errors due to a lack of knowledge of the rules, limits and conditions of validity of statistical data analysis methods. Theoretically, it seems that our method may lead to a situation where no interval is suitable for removing outliers. However, in practice, the method is always able to deal adequately with outliers. One avenue for reflection would therefore be to examine the theoretical convergence of the algorithm regardless of the nature of the distribution of the quantitative variable used. This work is part of a series of research projects aimed at automating the analysis of a quantitative variable. It follows on from a method we have developed and published, which allows the automatic identification of the symmetrical or non-symmetrical nature of the distribution of a quantitative variable without the use of graphs or statistical tests. Future research may address the development of a method for automating the process underlying the Stem-and-Leaf tool, which will make it possible to automatically analyze a quantitative variable according to the Exploratory Data Analysis approach as advocated by John Turkey. Such a perspective is necessary if we want to make it possible to develop effective analytical solutions in the context of BI 4.0 and pave the way for real-time statistics for the analytical needs of the Internet of Things.

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Analysis of the Use of Technological Tools in University Higher Education using the Soft Systems Methodology

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***Abstract*—This article analyzes the professional training of students according to the current situation. Students are experiencing a new modality of study due to the Covid-19 and specialists have to evaluate which would be the best solutions in order that students achieve greater understanding, because they are one of the most affected today. Therefore, we will be able to analyze in a detailed way each one of the causes that our problem presents to evaluate and thus to be able to obtain the different points of view of those who are involved in this problem. In this study we will apply the methodology of the soft systems with a systemic approach and a holistic vision to analyze the situation presented by all those involved. Having as results that it is necessary to evaluate in a better way the solutions that are given to higher education institutions, since it should have as main objective the achievement of a better teaching towards the students and thus opting for the use of good methodologies of learning.**

***Keywords*—Soft system; involved; university; virtual classroom; students**

I. Introduction

This research reveals the work done based on the virtual classroom. The work consists of determining each of the procedures to be followed and controlling the regulations to be complied with through the implementation of a methodology that feeds the teachers. The complete study shows the results for the correct use of the platform that is the classroom virtual, helping both the university and all those involved. The updating of information and communication technologies in the educational field has allowed redesigning the scenarios where the teaching-learning processes takes place, which has caused the barrier between face-to-face, blended and virtual education to be increasingly shorter and equally between formal, non-formal and informal education; where the roles of teacher and student must change as stated by Salinas [1]. For instance, in Peru ICT are allowing to the population to access more easily internet [2]. In this way, a true revolution in the way of conceiving learning experiences is produced when compared to the way it was done before. It is important to indicate that a global level there is a massive identify of LMS (Learning Management Systems) platforms in practice [3]. The conditions of the new world, where knowledge is the most important heritage of humanity, make the educational models and, therefore, the institutions that have the social responsibility to form, radically renew their pedagogical practices and their ways of handling the learning. These aspects require the presence of teachers with more interdisciplinary training, with new and renewed methodological visions and with more capacity for the rational and adequate use of the available means, especially of the new information and communication technologies (ICT). Today's universities are recognized for their qualities: among others, for the quality of their teachers and, above all, for their ability to cope with the permanent changes demanded by the globalized world [4] in this perspective the use of (ICT) as a didactic and pedagogical strategy in teaching practices takes on great importance [5]. The fundamental concept implicit in the latest online education experiences is the "VIRTUAL CLASSROOM", we wanted to do an analysis to propose and incorporate the use of Virtual Classrooms in Education as a technological support for teaching-learning that goes beyond what traditional classroom attendance represents [6]. Dr. Bello Díaz [7] calls virtual environments for learning "classrooms without walls" and affirms that it is a virtual social space, whose best current exponent is the internet, it is not face-to-face, but representative, it is not proximal, but distal, it is not synchronous, but metachronous, and it is not based on spatial enclosures with interior, border and exterior, but rather depends on electronic networks whose interaction nodes may be scattered throughout different countries [8]. In recent years, technological innovations and social needs have become part of the difficulties of the environment, and these, together with those of the political sphere, are what make universities aware of the need to redefine their mission. Faced with this, Information and Communication Technologies (hereinafter ICT) not only allow universities to transform their administrative procedures, innovate their teaching-learning methodologies or facilitate access to new groups of people - especially adults, but also promote a transformation in your organizational system. In this way, the ICTs affected by the structure of the university organization, its processes and its value chain [9] is why the use of the virtual platform will be implemented to speed up the teaching process. The objective of this article is to analyze the use of technological tools, as well as the strategy in virtual teaching, using the soft systems methodology.

II. Methodology

In this study, the methodology of soft systems is used, in order to be able to analyze the technologies of university higher education. To achieve the study of this research, the mnemonic CATDWE is applied in the different stages to evaluate the perceptions of the different stakeholders. Later, in Section 3, we will explain the results by taking the studies and perspectives of those involved.

A brief explanation of the acronym CATDWE will follow [10]:

C: Client, which in these cases may be the provider, since they are the ones involved in the different problems to be analyzed.

A: Actor, who is in charge of executing the different actions that will be carried out to solve the problem being analyzed.

T: Transformation, at this point the current situation of the problem is analyzed in order to propose the future situation they hope to achieve.

D: Owner, are those who are responsible for the execution of the process that was analyzed, for its proper solution.

W: Weltannshaunng, are the different points of view that present the involved ones, which will be taken into account for the solutions.

E: Environment, are the different restrictions which limit the complete execution of the solutions, these restrictions must be identified and taken into account before making a solution plan.

III. Case Study

A. Unstructured Situation

In this first stage the problem will be described as well as the causes found within this research work, therefore, we consider that the central problem is focused on the teaching process and on virtual learning in education provided at a higher level or in universities, taking into account different important points, which we highlight as the causes of this research. Therefore, as the first cause we have the virtual classroom, considered worldwide as a very efficient means by which fluid communication between the student and the teacher can be achieved, facilitating what has been learned in the different classes, either providing support with homework. or evaluations so that greater progress and understanding of the student is obtained. [11], managing to resemble a face-to-face mode, since inquiries towards teachers take much longer to be answered, managing to not satisfy their concerns. [12]. As a second cause we have resources, which are the most important and necessary technological means for students, as well as for teachers, since the use of Information and Communication Technology (ICT) is considered a key factor, having So within the ICTs, we work with two essential technological resources such as virtual platforms (PV) and the virtual learning environment (EVA), since these two together provide tools which can be controlled by the tutor or the administrator [13], which can allow you to browse the Internet properly or allow you to correctly install the programs and applications that can facilitate your virtual studies [14]. Having, as a third cause to teaching, these within the environment of the teacher should have incorporated certain didactic materials so that knowledge can be expedited through different texts, images, videos or animations for the best understanding of the students [15]. For in Spain, the main objective is to encourage, tutor and be able to evaluate the different activities of intellectual participation that the students have [16], which therefore are proposed by the teacher to achieve great ease in the processing of information [17]. Thus we managed to have as a clear example of teaching strategies the use of forums, in which each student can express what was understood or learned in class, this was achieved by developing a large number of tools that have been implemented currently [18] , taking as an example the research carried out at the University of León between the years 2009 to 2010, which shows the different dynamic perspectives such as integrating PPT in the virtual classroom, achieving a methodology, which tries to provide , information, training and help to give a series of information simultaneously to different participants according to their due disposition of technologies [19]. Other research that has focused on analyzing the type of practices developed by university professors through the platforms managed to reflect that the use of this methodology tends to reproduce educational models in a classical way, of which they are more oriented to transmission of information that to the participation of the students [20].

B. Structured Situation

In Fig. 1, you can see the stakeholders identified within the use of the Virtual Classroom are:

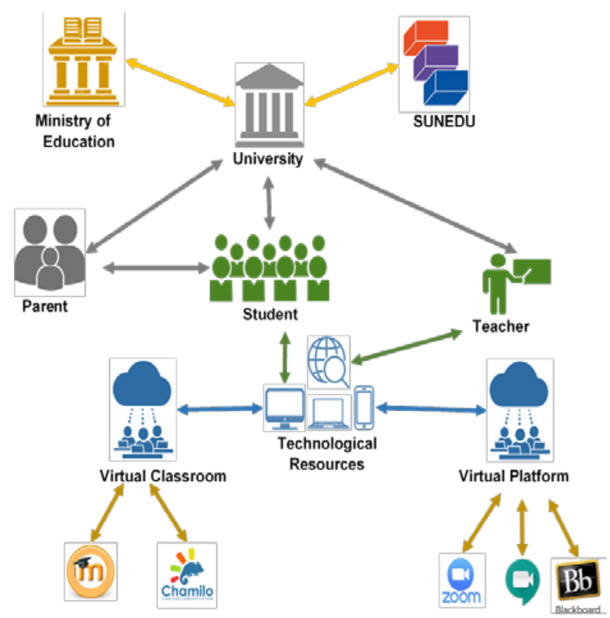


Fig. 1. Stakeholder Structure.

C. Basic Definition

- **W1. STUDENT:** The student is that subject whose main occupation is the activity of studying, perceiving it through the academic environment. Being the main function of the students to learn always new things about different subjects or branches of science and art, or any other area that can be put in study. Bearing in mind that the student carries out both the reading and the practice of the subject or theme on which he is learning [21].

C: Student, Teacher, University

A: Ministry of Education, Sunedu

T: In the transformation, two different visions can be observed, such as the current and future situation of the students, as seen in Fig. 2.

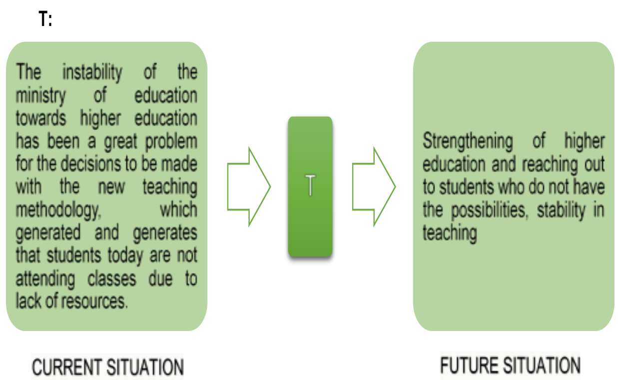


Fig. 2. Basic Definition of Students.

D: Government, Teachers, University.

W: To establish good learning among all students, the teaching methodology should be better evaluated, as well as the necessary resources that should be implemented in each higher education center.

E: Ministry of Education, Government.

- **W2. TEACHER**: An individual who teaches an art or a science, who carries out actions related to teaching at a professional level, since his work in transmitting knowledge and techniques, which are achieved by promoting student learning [22].

C: Student, Teacher, University

A: Ministry of Education, Sunedu

T: In the transformation, two different visions can be observed, such as the current and future situation of the teacher, as seen in Fig. 3.

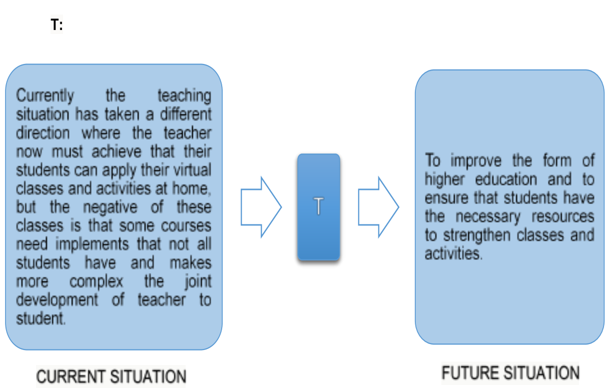


Fig. 3. Basic Definition of Teacher.

D: Government, SUNEDU, University

W: Better use should be made of all the possibilities so that the objectives associated with the professional preparation of the student can be met and that training in work skills can be provided for positive integration into the knowledge society and lifelong learning.

E: Ministry of Education, Government

- **W3. UNIVERSITY:** A university is an institution of higher education, which is divided into faculties according to the specialties of study that it can offer. The term also applies to the building intended for higher education, that is, an institution organized for the mutual benefit and legal protection of this group [23].

C: Student, Teacher, University

A: Government, Ministry of Education, Sunedu

T: In the transformation, two different visions can be observed, such as the current and future situation of the university, as seen in Fig. 4.

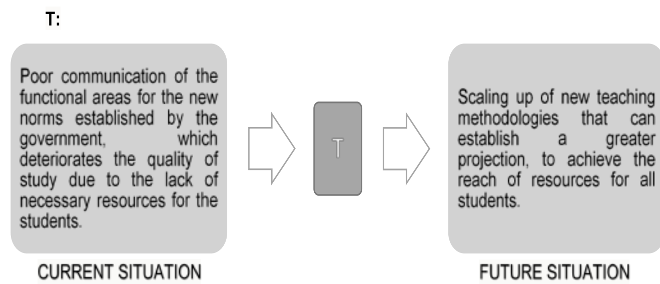


Fig. 4. Basic Definition of University.

D: Government, Ministry of Education, Sunedu, University

W: The problem has taken an exponential turn very quickly which has generated that communication in the academic environment has become difficult to manage and the delimitation of the resources of each student for the production of learning has not been handled correctly so there should be a reinforcement in the selection of regulations according to study methodologies.

E: Government, Ministry of Education, Sunedu

- **W4. MINISTRY OF EDUCATION:** The MINEDU is a main body that governs national education policies, which aim to generate opportunities as well as quality to all students to achieve greater development and national competitiveness and teachers strengthen their ability to exercise professionally [24].

C: Student, Teacher, University

A: Government, Ministry of Education, SUNEDU

T: In the transformation, two different visions can be observed, such as the current and future situation of Ministry of Education, as seen in Fig. 5.

T:

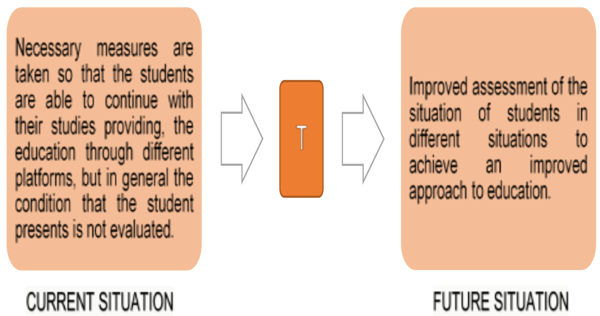


Fig. 5. Basic Definition of Ministry of Education.

D: Government, Sunedu, Ministry of Education

W: To be able to evaluate the different situations that students in general can present is very difficult, since in our country there is a large percentage of students who do not have the resources or economic means necessary to continue with an adequate education.

E: Government, Sunedu

- **W5. SUNEDU:** SUNEDU is responsible for providing licensing to achieve a good service in university higher education, being thus the organization to evaluate the basic conditions of quality as well as to control public resources and correctly administer the national records of degrees and titles [25].

C: Student, Teacher, University

A: Government, Ministry of Education, SUNEDU

T: In the transformation, two different visions can be observed, such as the current and future situation of the SUNEDU, as seen in Fig. 6.

T:

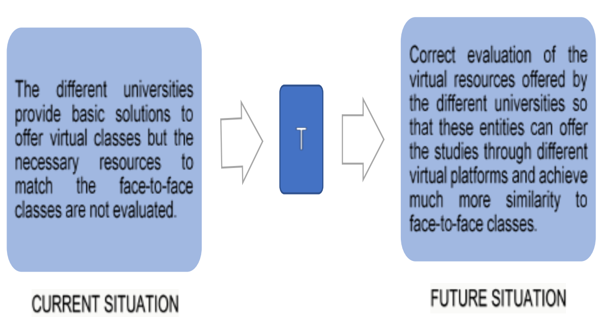


Fig. 6. Basic Definition of SUNEDU.

D: Government, Sunedu, Ministry of Education

W: The different universities evaluate the best way to offer their virtual classes, but many of them do not manage to facilitate or resemble certain activities as they would be in a face-to-face way.

E: Government, Ministry of Education

- **W6. VIRTUAL PLATFORM:** It is known as a system, which can be considered in a technological environment, this achieves the execution of different applications, making the user access through the internet, that is to say that to be able to use it it will not be necessary to be in a specific place, since the only thing that we would need for its due use would be the safe connection to the web. These virtual platforms are generally used for everything related to distance education, because there is a tendency to register the learning in the classroom [26].

C: Student, Teacher, University

A: Ministry of Education, SUNEDU

T: In the transformation, two different visions can be observed, such as the current and future situation of the Virtual Platform, as seen in Fig. 7.

T:

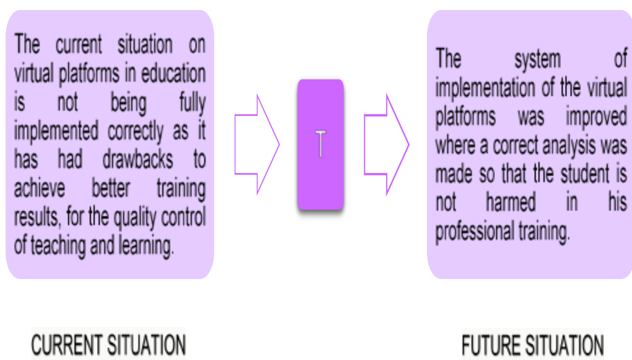


Fig. 7. Basic Definition of Virtual Platform.

D: University, SUNEDU

W: To establish a good use of the virtual platforms between teacher and student it would be necessary to have an evaluation system where the students can count on the necessary resources and so they can have a stable professional education to their working life.

E: Ministry of Education, Government, SUNEDU

- **W7. PARENTS:** These are individuals or groups of people who are considered a minimum social unit, consisting of a mother and a father, who promote behavior through education in accordance with moral and social values, thus forming the child's educational process [27].

C: Student, Parent, University

A: Ministry of Education, Sunedu

T: In the transformation, two different visions can be observed, such as the current and future situation of the Parents, as seen in Fig. 8.

T:

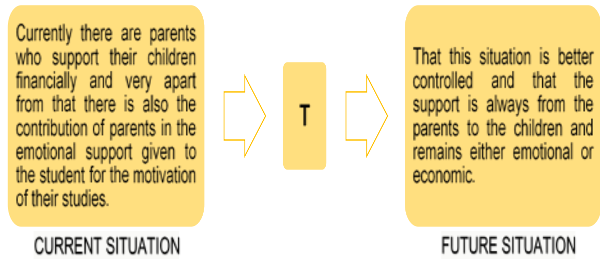


Fig. 8. Basic Definition of Parents.

D: Government, Students, University

W: This situation has harmed the student in such a way that he or she cannot pay the resources of the university since many of them have the financial support of their parents and apart from the emotional support that they give them and the student's performance improves because of the situation many have been affected considerably.

E: Ministry of Education, Government

- **W8. Virtual classroom:** It is known as a digital environment with the possibility of achieving a good development of learning processes. Therefore, information and communication technologies (ICT) allow the student to quickly access the uploaded material and in turn interact with the teacher or other students. [28].

C: Student, Teacher, University

A: Ministry of Education, SUNEDU

T: In the transformation, two different visions can be observed, such as the current and future situation of the Virtual classroom, as seen in Fig. 9.

T:

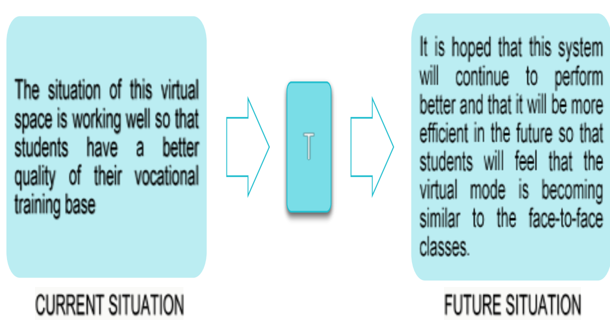


Fig. 9. Basic Definition of Virtual Classroom.

D: SUNEDU, University

W: It offers us as students facilities such as a more centralized site where we can access the introduction and objectives of learning, also with this modality you can have interaction with colleagues and with the same teachers who can absolve our doubts.

E: Ministry of Education, Government, SUNEDU

D. Conceptual Models

After analyzing the CATDWE, which has an input and output formed in the transformation, for this reason a conceptual model was carried out for each of those involved, which are made up of activities that start with an action verb, thus having a total of 33 activities, with which after an analysis 9 confirmed activities were achieved.

– **List of Confirmed Activities**

1) To achieve better development by classifying students who have resources and those who do not in order to achieve better education.

2) To implement methodologies to improve the effectiveness of student teaching by achieving active participation and progress in the practical environment.

3) Provide public recognition and incentives to entities, which establish alliances for the benefit of the student by providing them with scholarships and technological resources.

4) Provide guidance to students and teachers of the different virtual platforms that can be implemented for virtual classes.

5) Determine the mastery of the content presented by the teacher for students in individual and group work according to the resources used in class

6) Improve the use of study tools so that the student has his knowledge reinforced with the implementation of forums and videos to support the classes taught.

7) To carry out surveys and evaluations to the students in order to know in a fast and efficient way with the help of computer tools, obtaining results about their current situation.

8) Carry out a support plan with the help of parents to evaluate and encourage the academic performance of students by visiting the facilities.

9) Monitoring Activities.

E. Primary Task Model Confirmed

BASIC DEFINITION: A concept that has been developed since the 1980s, this term is attributed to ROXANNE HILTZ who defines it as "the use of computer-mediated communications to create an electronic environment similar to the forms of communication that normally occur in the conventional classroom". [29].

CATDWE ANALYSIS:

C: Students, Teachers, University

A: Ministry of Education, Sunedu

T: In the transformation, two different visions can be observed, such as the current and future situation of the primary task model confirmed, as seen in Fig. 10.

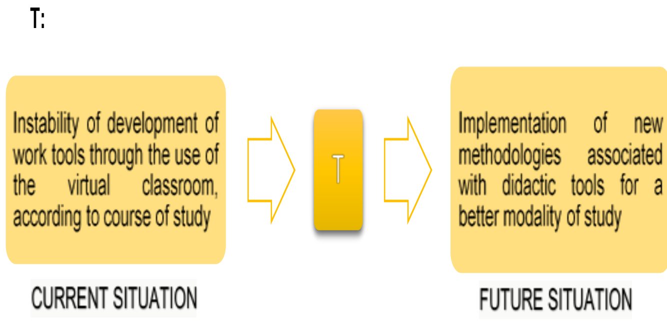


Fig. 10. Primary Task Model Confirmed.

D: Government, Teachers University

W: The use of the virtual classroom speeds up the progress of teaching, but more work tools must be implemented to improve this modality of study.

E: Ministry of Education, Government

In Fig. 11 shows the conceptual model of confirmed and validated tasks, which are related between the control of activities, fearing the situation of the present as input and the future situation as output.

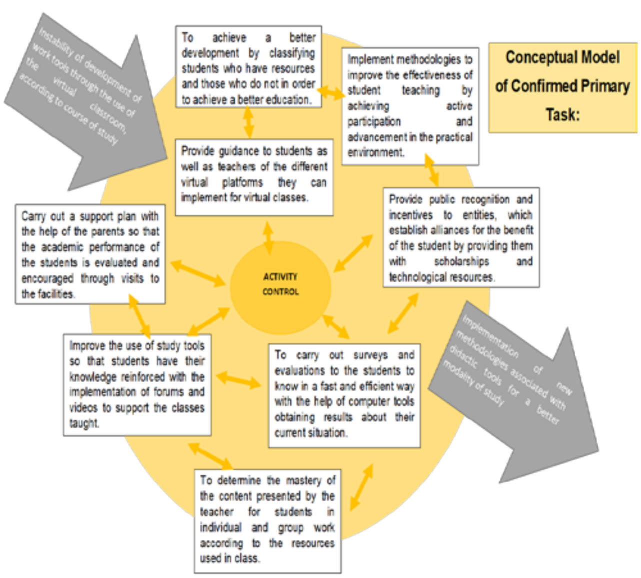


Fig. 11. Conceptual Model of Confirmed Primary Task.

F. Confirmed and Validated Primary Task Model

BASIC DEFINITION: It is a platform that gives the users the necessary tools to learn, it is a very efficient way to obtain information, and it supports the students with the materials that the teachers use [30].

CATDWE ANALYSIS:

C: Students, teachers, universities

A: Ministry of Education, Sunedu

T: In the transformation, two different visions can be observed, such as the current and future situation of the confirmed and validated task model, as seen in Fig. 12.

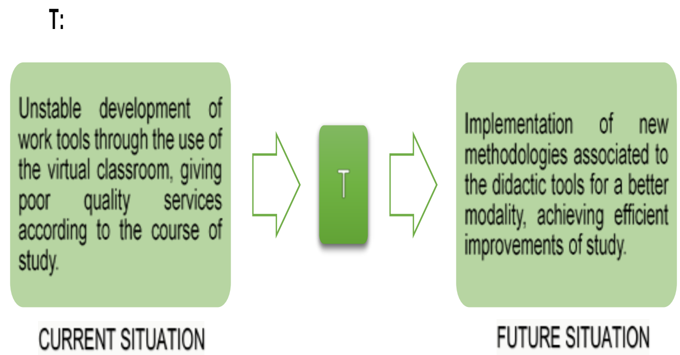


Fig. 12. Confirmed and Validated Primary Task Model Confirmed.

D: Ministry of Education

W: This provides information to the different students, in addition to the face-to-face class and because in this one can add books, videos as a reference to complete the information explained previously, the knowledge obtained can also be evaluated.

E: Ministry of Education, Government.

In Fig. 13 shows the conceptual model of confirmed and validated tasks, which are related between the control of activities, fearing the situation of the present as input and the future situation as output.

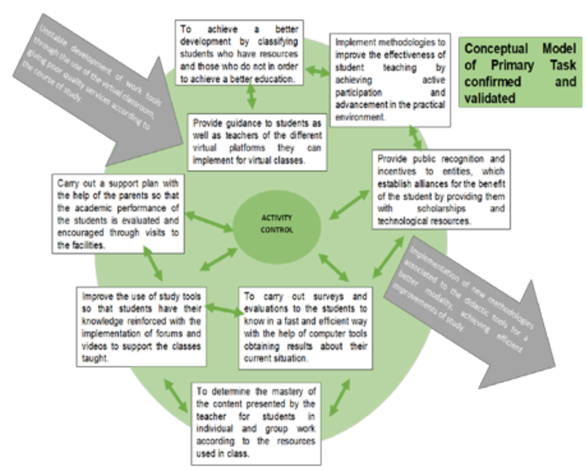


Fig. 13. Confirmed and Validated Primary Task Conceptual Model.

G. Categories of Information

In this section we analyze the activities that we have confirmed and validated in which different activities were assigned within the inputs as outputs, as can be seen in Table I.

TABLE I. (A) CATEGORIES OF INFORMATION

Activity	Achieve better development by classifying students who have resources and those who do not to achieve better teaching.	Implement methodologies to improve the effectiveness of student teaching, achieving active participation and advancement in the practical environment.	Provide public recognition and incentives to entities that establish alliances for the benefit of the student, provide them with scholarships and technological resources.	Provide guidance to students and teachers of the different virtual platforms that they can implement for virtual classes.
INPUT	Conduct surveys of the tools that will be used.	Implement study models.	Establish alliances with academic value.	Carry out an orientation schedule.
	Make a report of the notes.	Implement much more student participation	Establish the correct use of these platforms	
OUTPUT	Evaluate survey	Evaluate students and review improvements	Generate academic proposals for students.	List of participants.
	Evaluate notes	Answer the students' doubts.	Winning awards regarding your high competition.	Topics to play.

(B) CATEGORIES OF INFORMATION

Activity	Determine the mastery of the content that the teacher presents for the students in individual and group work according to the resources used in class.	Improve the use of study tools so that the student has their knowledge reinforced with the implementation of forums and videos to support the classes taught.	Carry out surveys and evaluations to the students to know quickly and efficiently with the help of computer tools achieving results on their current situation.	Make a support plan with the help of parents so that the academic performance of students is evaluated and encouraged by making visits to the facilities.	Control Activities
INPUT	Survey students about classes.	Survey on programs less used by students. Make support videos of the classes.	Carry out some surveys for the students.	Invitation to parents.	Coordination report
					Work plans.
					Schedules for activities.
OUTPUT	Evaluate the results obtained for possible improvements.	Survey on programs less used by students.	Quickly obtain and evaluate results.	Encourage improved student development.	Report progress.
		Make support videos of the classes.			Activity control report.

IV. RESULTS

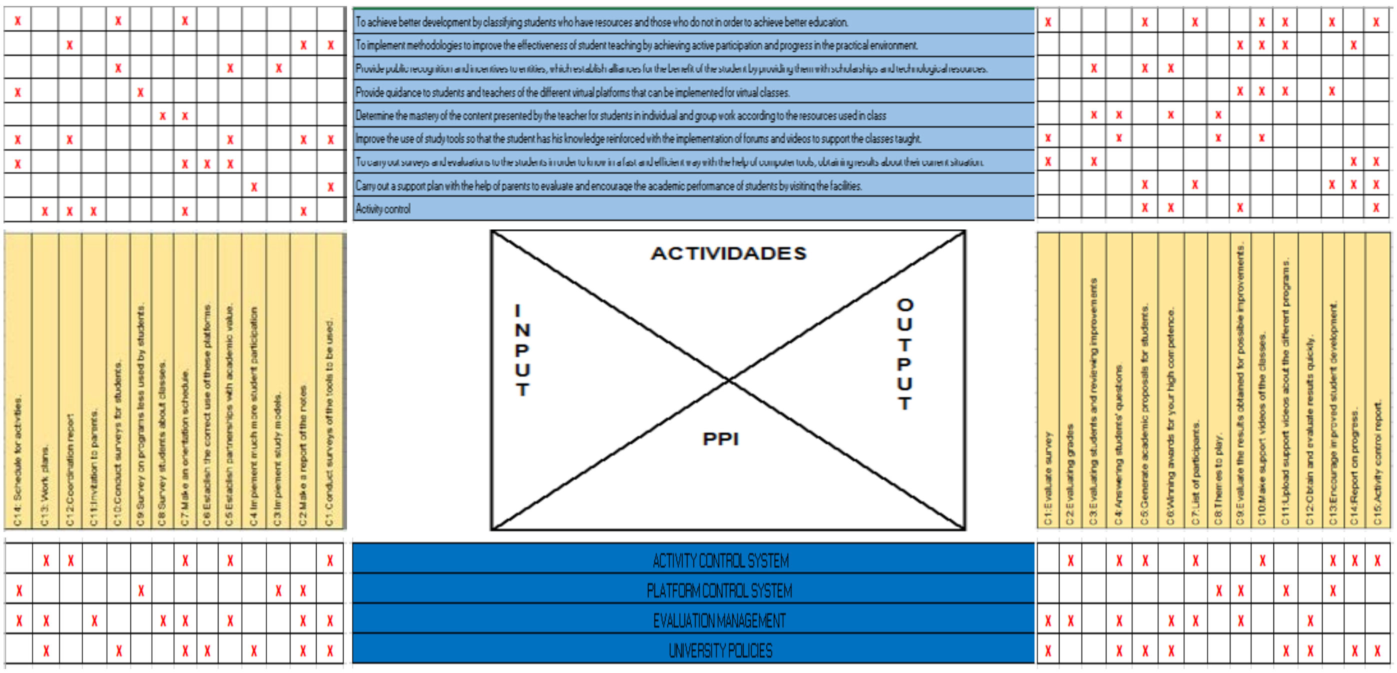
A. Malta Cross

The Maltese cross is mostly used to be able to analyze the different cardinal points that the problem presents, making combinations between them and thus achieve a good proposal for improvement, as seen in Table II.

B. Analysis Regarding the Malt Cross

- **NORTH WEST VS. NORTH EAST:** Universities need quality education that can adapt to situations such as when students have to have materials for their studies, as well as establishing awards to encourage their development and help with different methodologies that help even in the platforms that are being used.
- **SOUTH WEST VS. SOUTH EAST:** Different systems should be implemented to help control students. In addition, materials and information should be available and assessments should be established to help monitor student progress.
- **NORTH EAST VS SOUTH EAST:** To monitor the progress of the students it will be necessary to implement different methodologies that help with their progress, they will also have to be evaluated and use the different tools they have.
- **NORTH WEST VS SOUTH WEST:** To keep us informed about what students need and have, it is necessary to establish surveys in addition to promoting student progress.
- **NORTH WEST VS SOUTH EAST:** Taking into account the willingness of those involved to complete the various surveys that will be sent to you, so that you can help the collective progress and keep track.
- **NORTH EAST VS SOUTH WEST:** They want to implement better education and support in the different services they need.

TABLE II. MALTA CROSS



V. CONCLUSIONS

With this research we can conclude that the different universities must first carefully analyze all the factors and situations presented by those involved in virtual education, so that they can have better control of activities such as assessment, tasks, forum, correct use platform moddle, and the zoom videoconferences that will be carried out, implementing different methodological systems in the training of teachers, since the central focus must be taken into account for the correct virtual education, advice to teachers and students, to teach them the proper use and implementation of the different tools that can be established in your classes and you can give a good evaluation with the use of these tools. In addition, the Ministry of Education must propose adequate policies to socialize the use of the Internet to the vast majority, that is, to shorten the digital divide and thus be able to obtain a virtual education, taking as a clear example European countries, which before taking any decision regarding education, they always take as central beneficiaries the students, achieving a collective improvement and new innovations within their education, since they take due time for the correct implementation and evaluation of the necessary requirements so that in a university It can include virtual study and there are no differences with classroom classes.

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Effective Opinion Words Extraction for Food Reviews Classification

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***Abstract*—Opinion mining (known as sentiment analysis or emotion Artificial Intelligence) holds important roles for e-commerce and benefits to numerous business and organizations. It studies the use of natural language processing, text analysis, computational linguistics, and biometrics to provide us business valuable insights into how people feel about our product brand or service. In this study, we investigate reviews from *Amazon Fine Food Reviews* dataset including about 500,000 reviews and propose a method to transform reviews into features including Opinion Words which then can be used for reviews classification tasks by machine learning algorithms. From the obtained results, we evaluate useful Opinion Words which can be informative to identify whether the review is positive or negative.**

***Keywords*—Review classification; opinion words; machine learning; important features; Amazon**

I. Introduction

Along with the strong development of Internet, e-commerce applications, social media such as reviews, forums, blogs, Facebook are increasingly popular. In order to effectively exploit the source of opinion data that users have implemented to evaluate products or raise their views on an issue they are interested in.From there, providing them with useful decisions suitable for individuals, organizations, opinion mining or sentiment analysis system is considered as a decision support tool. The main purpose of opinion mining [19][20] is the research to analyze, calculate the human viewpoints, assessments, attitudes and emotions about objects. such as products, services, organizations, individuals, problems, events, topics, and their various aspects.Opinion mining into three issues as follows: Document-based opinion mining: this is the level of simplicity of opinion mining, the document contains a point of view about a main object expressed by the author of the document. There are two main ways to explore material-based perspectives supervised and unsupervised learning. Sentence-based opinion mining: A single document can contain multiple perspectives even on similar entities. When a more detailed analysis of the various perspectives expressed in the entity documents is sought, a point-based concept mining is carried out. Aspect-based or feature-based opinion mining: research is a research problem focused on identifying all Emotional manifestations in a given document and the aspects they refer to. The previous two methods work well when the entire document or each sentence refers to a single entity. However, in many cases, when referring to entities with many aspects (many attributes) and different views on each of the above aspects. This usually happens in product reviews or in discussion forums specific to specific product categories.

Currently, the main approaches to building a opinion mining system include lexicon-based approach [21] and approach machine learning-based [22], hybrid-based approach [22], and recently there is an in-depth approach (deep learning-based) [24]. For lexicon-based approaches, the sentiment dictionary and sentinel words are used to determine polarity. There are three techniques [20] for building an emotional vocabulary: manual-based, corpus-based, and dictionary-based approach.These methods have the advantage that emotional vocabulary has broad knowledge. However, the finite number of words in the vocabulary and the emotional score are permanently assigned to the words in the text [23]. For machine learning-based approach that uses classification techniques to conduct perspective classification, it consists of two data sets: training data set and test data set. Training sets are used to learn the different characteristics of a document, while test sets are used to test the effectiveness of the classifier.The approaches of machine learning method to classify views such as: specific probability classification are Naive Bayes, Bayesian Network, Maximum Entropy used [25]; classification based on decision trees [26]; linear classification as SVM (Support Vector Machine) [25] or Neural Network; rule-based classification. Machine-based approaches are adaptable and create models for contextual specific purposes. However, the applicability is low for new data because it requires the labeling data that can be expensive, the learning ability of machine learning models is weak, so the predictive accuracy is not high. For hybrid-based approaches [23] is a combination of machine learning and vocabulary-based approaches to improve classification performance. However, the drawback of this method is that the assessment documents have a lot of noise from words not related to the entity or aspect of the assessment) are usually assigned a neutral point because the method does not detect any public opinion.

To enhance the predictive performance of the classification algorithm to achieve high classification efficiency, solve large-scale data problems and overcome limitations when exploring views for New classes are included in the training system during the test because some learned models are not able to handle new unknown classes. Ensemple methods overcome these limitations and aim to have a strong model by combining training decisions across categories rather than on a single classification.The ensemble methods have greater flexibility and generalization than a single classification. In this paper, we propose a method to convert assessments into features that include opinion words that can then be used to evaluate classification tasks using the ensemble learning algorithm. with the same weak learning sets such as Decision Tree Classification (dtc), Gradient Boosting Classifier (gbc), Random Forest (rf).

The rest of this paper is organized as follows. Section II presents related work. Section III presents our proposed method for classification for reviews based on the proposed set of feeling words. Section IV shows the experiments with three ensemble methods on Amazon Fine Foods reviews. The conclusion of the paper is presented in Section V.

II. Related Work

Text classification [9] is considered as the act of dividing a set of input documents into two or more categories where each document can be said to belong to one or multiple classes. Large growth of information flows and especially the explosive growth of Internet and computer network promoted growth of automated text classification. Development and advancements in computer hardware can provide enough computing power to allow automated text classification to be used in practical applications. Text classification is popularly used to handle spam emails, classify large text collections into topical categories, manage knowledge and also to help Internet search engines.

Numerous studies have proposed robust algorithms for Natural language processing. Jyoti Yadav et al. [1] proposed to use K-means algorithms as the preferred partitional clustering methodology. The algorithm removed the requirement of specifying the value of k in advance practically which is very difficult. This algorithmic program can obtain the best variety of cluster Second algorithmic program cut back complexity. Some algorithmic programs use data structure that will be used to store information in every iteration which information will be employed in the next iteration. It increases the speed of clustering and cut back complexity.

In [4], the authors deployed The Bag of Words (BoW) model learns a vocabulary from all of the documents, then models every document by reckoning the number of times every word seems. The BoW model could be a simplifying illustration utilized in Natural Language Processing and information retrieval. BoW is employed in Computer Vision. In Computer Vision applications, the BoW model was applied to image classification tasks.

In [3] Zahra Nazari proposed a general definition of clustering is “organizing a bunch of objects that share similar characteristics”. The purpose of clustering is organizing data into clusters. Such that there were high intra-cluster and low inter-cluster similarity. Hierarchical methods are commonly used for clustering in data mining problems. A hierarchical method can be subdivided as follows.

In [7] authors proposed a “New Hierarchical Clustering Algorithm” to reduce the terms some features selection technique should be used. TF-IDF technique was used which eliminates the most common terms and extracts only the most relevant term s from the corpus. Preprocessing was done by removing noisy data that can affect clustering results. Stopwords Removal and Stemming. Term Frequency-Inverse Document Frequency algorithm was used along with K-means and hierarchical algorithm

In [13], authors stated that Sentiment analysis and text summarising uses natural language processing, machine learning, text analysis, statistical and linguistic knowledge to analyze, identify and extract information from documents. The method was generally used to determine the emotions, sentiments, and summarising from large data and that information can be used to make some predictions. This work basically consisted of two machine learning methods Naive Bayes Classifier and Support Vector Machines(SVM).

Stefano Baccianella et al. released SentiWordNet 3.0 for English [8], built on the basis of WordNet 3.0. The authors built SentiWordNet 3.0 through two steps: (1) semi-supervised learning and (2) random transformation steps.

III. Classification Methods for Review based on the proposed set of feeling words

We proposed method contains four component as shown in Fig. 1. Reviews extracted from Amazon dataset are pre-processed into option words. The set of words then transformed by Doc2vec algorithm to become features and values for the dataset.

A. Dataset Description

We have investigated food reviews data sets and run different ensemble learning models for review classification and useful feature extraction from tree-based decision algorithms. Food reviews data sets from amazon contains over 500,000 reviews. Each product review includes information on user, rating, and review text. The details of this data set are shown in Table I [18]. The investigated reviews are written by over 200,000 users for 74,258 products. 260 users have provided over 50 reviews. The average length of each review is about 56 words.

We only retain the content of reviews and their labels (negative or positive), and remove other information. We also remove duplicate reviews to ensure contents of review being unique. Through the pre-processing process, we have the training and test data set as input data for the machine learning classifier, shown in Table II. The contents of review, then will be processed and described in the next sections.

B. Pre-Processing

The review texts always contain numbers, special characters, stop words, etc. Some words can appear frequently in sentences but they do not contribute the meaning of the

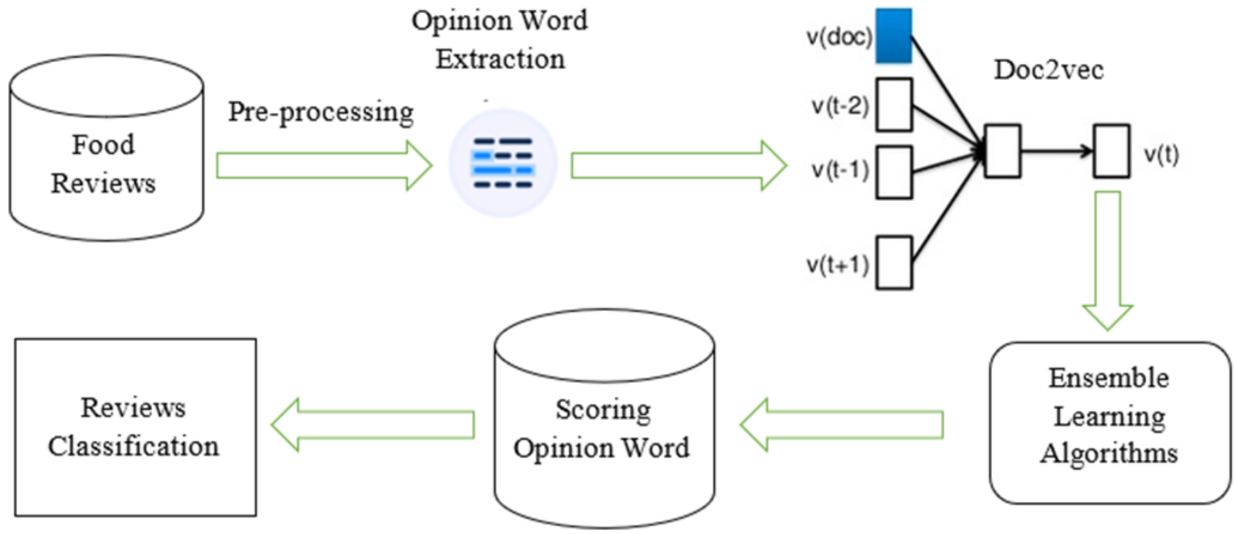

Fig. 1. An Opinion Words Extraction and Reviews Classification

TABLE I. Data detail

Dataset statistics	Number of records
Reviews	568,454
Users	256,059
Products	74,258
Users with >50 reviews	260
Median no. of words per review	56

TABLE II. Data train and test

Dataset statistics	Number of records
Reviews	18532
Train	14825
Test	3707

sentences (For example, prepositions such as on, the, at, etc.). We have separated the words in the reviews into tokens and removed the unnecessary words by using the NLTK tool [12]. This is a tool for text analysis in natural language processing. The remaining words can bring the meaning of the sentences including nouns, noun phrases, verbs, adjectives, and adverbs, so we can find participation of those types of words in each product review to determine the meaning of the reviews.

C. Opinion Word Extraction

We performed opinion words extraction to sentiment expression from product reviews. For example such as “good”, “bad”, “great”, “better”, etc. These words are often of the adjectives, adverbs and adjectives by using the OpinionFinder [14] tool. This tool is a document processing system and automatically identifies subjective sentences as well as various aspects of subjective sentences, opinion words extraction to sentiment expression in reviews [15]. For each product review, we have extracted opinion word expressed as the attributes of the review. Next step, we perform training on the doc2vec model to determine the weight of each opinion word and each reviews.

D. Doc2vec

Doc2vec or Paragraph vector [11] is a method of vectorizing text. The Doc2vec method is similar to word2vec [16] but instead of representing the word vector while the Doc2vec method will represent the document as vector. There are two ways of building a Doc2vec model: Distributed Memory version of Paragraph Vector (PV-DM) and Distributed Bag of Words version of Paragraph Vector (PV-DBOW). The PV-DM model is an extension of the CBOW model of word2vec. The PV-DM model works on remembering what is missing in context, in a topic, or in a paragraph. The PV-DM model uses surrounding vectors (context) to predict target words. In addition, this model adds a vector attribute of a document. After training the word vector, the text vector will also follow. After training the word vector, the document vector will also follow. The output, the PV-DM model will give the vector index of the document. The word vector will represent the conceptual representation of a word, the document vector will represent a document.

The PV-DBOW model is similar to Skip-gram model of word2vec. But it trains faster and takes less memory than Skip-gram because there is no need to remember the words[11].This technique is used to train models when building a set of documentation requirements. Then, each word vector is created for each word and each document vector will be created for each document. The model outputs are vectors corresponding to the calculated new input.

In this paper, we approach both the PV-CBOW and PV-DBOW models to build a set of food assessment document

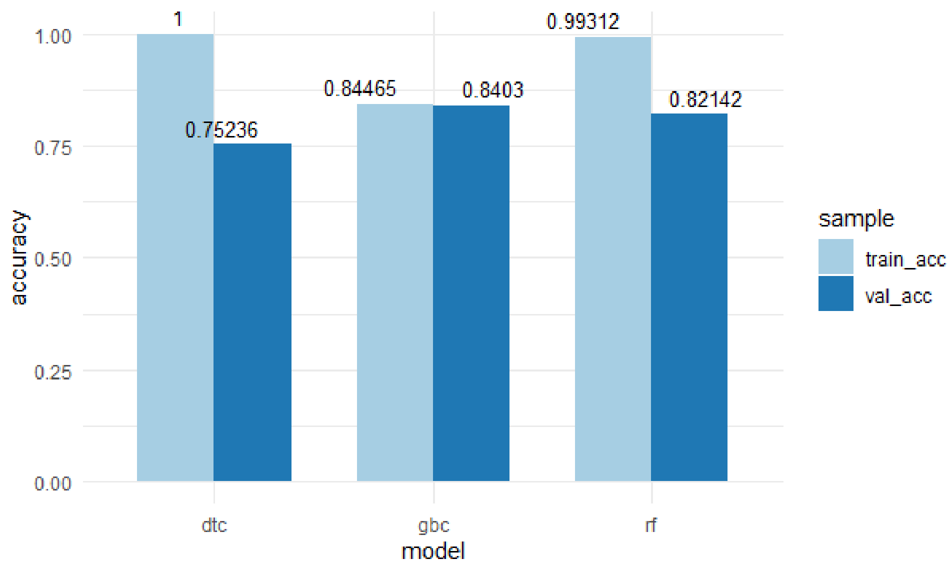

Fig. 2. Compare Accuracy of Three Classifiers DTC, RF, and GBC.

vectors based on the doc2vec model approach in the Gensim library.

E. Sentiment Classification

In order to classify reviews, we use robust machine learning including Gradient Boosting Classification, Random Forests and Decision Tree. Food assessment document vectors are input to classified as "positive" and "negative" by population methods with the same basic classification such as Decision Tree [2], Random Forest Algorithms [6], Gradient Boosting Classifiers [10], [5].

Decision Trees (DTs) [2] are a non-parametric supervised learning method used for classification and regression. The goal is to generate a learning model that predicts the value of a target category by learning simple decision rules inferred from the data features.

Random forests [6] or random decision forests are an ensemble learning method for classification. The algorithm is also used for regression and other tasks. This algorithm is rather robust to develop computation framework based machine learning with fast speed and give reasonable results.

Boosting [5] is a technique to transform weak learners to strong learners. Each new tree is a fit on a modified version of the original data set. Gradient Boosting Classifiers are esemble methods with similar weak base classifiers to improve the formation of a strong learning model. The idea of the 'Gradient Boosting" classification is based on PAC (Probability Approximately Correct Learning) [17]. In this study, we approach the Gradient boosting classification model on the dataset including the food evaluation document vector already developed above. The gradient boosting trees can be strong method to do prediction tasks.

IV. Experimental Results

In this section, we evaluate the efficiency of the set of opinion words on review classification tasks with the algorithms of Gradient Boosting Trees (GBC), Random Forests (RF) and Decision Tree (DTC).

A. Reviews Classification with Different Algorithms

Fig. 2 shows the prediction performance of the considered algorithms. We can see GBC reveals less overfitting compared to other algorithms. For Decision Tree Classifiers, although the training can reach to 100%, it shows the worst result in testing performance with only 0.752 in Accuracy. Otherwise, GBC only reveals the lowest performance in training phase but this algorithm can obtain to 0.845 in testing phase. Another case, Random Forest exhibits rather high both in training and testing phases. Random Forest obtain an accuracy of 0.821 which is higher than Decision Tree Classifiers but lower than Gradient Boosting Trees.

From the results obtained, we expect Gradient Boosting Trees can extract meaningful words to evaluate the reviews.

B. Useful Words to Determine the Meaning of the Reviews

For evaluating which words are useful to determine whether a review is negative or positive, we compute important scores extracted from all considered classifiers. As exhibited in Fig. 3, 4 and 5, words such as "good", "great" are the most influence words on characteristics of reviews. As Observed from these figures, the word of "great" hold an important to evaluate whether the review is negative or positive. We can find easily that the statements contain "great" expressing a satisfaction on the product. "good" and "better" also convey good feelings on the product. From the 4th important word, there are some slight differences among the considered algorithms. While GBC and RF provide "happy" and "love", respectively, which sound reasonably, the DTC shows the word of "healthy". Although, they both bring positive feelings but "healthy" affects a narrow scope comparing to "happy" and "love". This can lead to RF and GBC reveal better results than DTC.

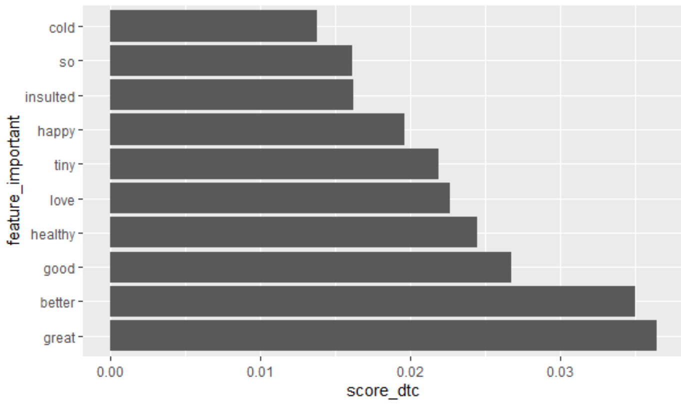

Fig. 3. TOP TEN Important Features in Food Reviews Generated from Decision Tree Classifiers.

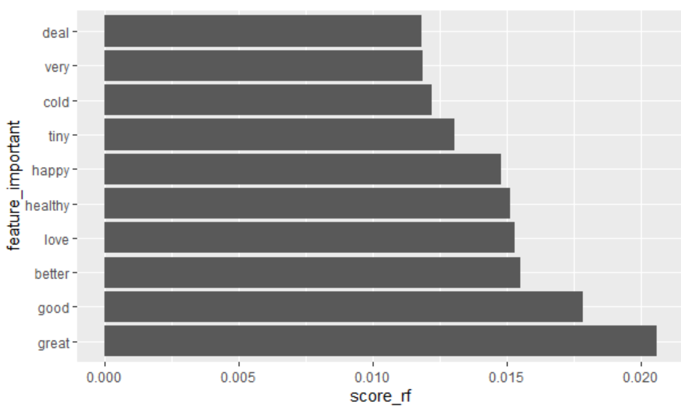

Fig. 4. TOP TEN Important Features in Food Reviews Extracted by Random Forest Algorithm.

Comparing the important scores among features shown those figures, we can see there are significant differences among the high important words in Gradient Boosting Trees while some words in other algorithms seem to be grouped such as "better" and "great" in Decision Trees or a group of "happy", "healthy", "love" and "better" in Random Forest.

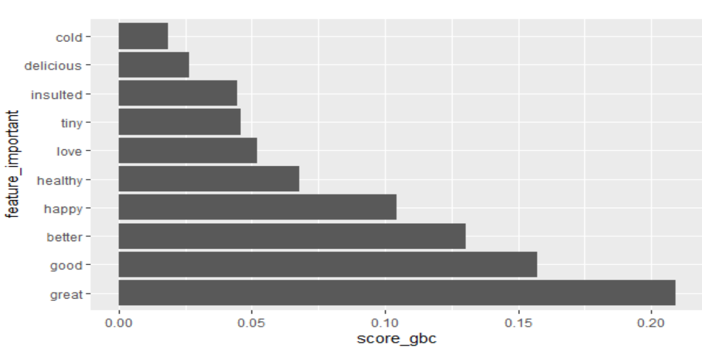

Fig. 5. TOP TEN Important Features in Food Reviews Generated from Gradient Boosting Classifiers.

V. Conclusion

We introduced a set of opinion words and useful words extracted from learning model to evaluate whether a review for food production on Amazon is negative or positive. The proposed approach can be possible to apply to other e-commerce systems. The proposed features can reach a promising result with classic machine learning algorithms.

Useful words extracted from Gradient Boosting classifier and Random Forests are interesting to predict which review is positive. Some words as observed from the results are rather familiar and common words to express the feeling when we use some product.

With achievements of deep learning techniques, further research can leverage to propose sophisticated models to improve the prediction.

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Novel Design and Implementation of a Vehicle Controlling and Tracking System

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***Abstruct*—The purpose of this project is to build a system that will quickly track the location of a stolen vehicle, thereby reducing the cost and effort of police. Moreover, the vehicle's computer system can be controlled remotely by the owners of the vehicle or police. More precisely, the goal of this work is to design a, develop remote control of the vehicle, and find the locations with Latitude (LAT) and Longitude (LONG).**

Keywords*—*Vehicle controlling; smart system; tracking system; microcontroller; messaging; GSM; GBS

I. Introduction

Vehicle theft is an existing phenomenon which is considered a common occurrence that extends beyond its security dimensions to economic, social, and psychological damages. Despite all the recent techniques and actions that have been taken to avoid vehicle theft, the National Crime Information Center (NICC) stated at the end of December 2014 that millions of vehicles were stolen and billions of dollars lost [1]. The same is true six years later. Therefore, many researchers address this crucial requirement to protect lives and assets.

The key concept of this research to design a system using the Global Positioning System (GPS), the Global System for Mobile communications (GSM) and a microcontroller that can control the vehicle when it is stolen [2,3,4,5]. GSM is directly connected to the microcontroller (which is an Arduino processor) and then connect the entire system to the GPS. The Short Message Service (SMS) is processed in the microcontroller unit and forward it to the GPS unit to give the exact location in the form of latitude and longitude on the owner's mobile phone. Some of the features of the system are: the ability to lock and unlock vehicle doors, find its position, turning on the lights, turn flashing lights [6].

Through this work, simple techniques used by everyone will be used to work on solving the problem of tracking the vehicles if they are stolen. The use of messaging technology in mobile phone networks is the cheapest, easiest and best way to communicate between the vehicle and its owner, through which the type of security of the system was determined by creating messages for each vehicle owner as desired. However, we achieved customer requirements as desired, by specifying the type of numerical messages or by letters. In what follows we present a literature review. After that we describe the system and at the end we draw the conclusions.

II. Literature Review

In the research of Rani et al. [7], it is described a system that is based on biometrics framework used for securing a vehicle. Biometric technology in the form of the driver's fingerprint recognition is used to start the engine. The system operates in two modes. The first mode is "*conformity*", which controls the proper operation of the vehicle, while the second mode is "*nonconformity*", which will alert the vehicle owner automatically by sending a message with GSM. It is also possible for this system not to allow a drunk driver or a driver when s/he fall asleep.

Sugumaran et al. presented a monitor system based on a "Raspberry pi" and an infrared sensor [8]. An infrared sensor is used to identify a specific area when many people enter an area. The system will turn on automatically when the system senses a movement. Then the information is sent to the owner's mobile.

A system designed for controlling a vehicle is also described by Kumar et al. [9]. This is done by controlling the fuel injection using an electronic solenoid valve through which a microcontroller controls the driver circuit. A passkey will be given to the owner of the vehicle in case of conformity and the solenoid valve will open and the vehicle will start. In case of unconformity the program will send to the owner a message through a 'GSM' modem connecting an alarm.

In the research of Ramadan et al. [10], it is presented an anti-theft and tracking system for the vehicles. By the direct connection with the owner of the vehicle the system can detect the areas and current settings of the vehicle, as well as, detecting the locations of a group of vehicles. This is done by using the "Google Earth".

A system created for mobile vehicle security provides a connection between the driver and the system, as described in the research of Shah et al. and Abdullah [11, 12]. In the case of intrusion, the system will send a '*warning message*' to the owner. Once the message is sent to the vehicle owner, she/he will be able to control all the vehicle safety features through his smartphone.

In the paper of Pany et al. [13], it is described a system installed in the engine of a vehicle with a 'GSM' modem connected to a microcontroller. The system offers multiple features to the owner. One such feature includes a password-protected engine start. If the password is correct, the system will authenticate and the car will start working. In case of nonconformity, the engine will not start and the siren will go on and the system will send a message to the car owner through the 'GSM' system [13].

As compared with the previous described system, ours has several distinctive features. For example, the system relies on two types of energy sources: the car battery and the portable battery that is used in case of an event of a car battery failure. The system allows the capability to replace the phone number for the system and the owner. Several operations were created on the vehicle that can be extended into multiple ones to control all car parts. The system has a high degree of security through the confidentiality of phone numbers and the way to verify them through the code which is used by the Arduino processor**.** If the authentication process succeeds, the system will begin to execute orders coming from the owner.

III. Research Methodology

The design is made in such a way to create an efficient process for real-time tracking and controlling any vehicle equipped with this technology, anywhere at any time. Our system which uses a microcontroller and traditional smartphone technologies can be done at lower cost and with larger flexibility as compared to other systems. The system works to integrate some global systems which are reliable and are able to give real results to the user, such as GPS, GSM and smartphone technology which are the most used methods to control and track vehicles [14,15,16,17,18]. The process of sending messages and executing the request is impacted by some problems, the most important one being the signal strength of the system network. The signal strength will affect the performance of the current system technology. It typically takes this system from four to six seconds to interact with the message and implementation.

The system can be developed significantly and efficiently to suit the evolving electronic world based on two directions. The first direction is to control the vehicle, while the second part is to easily track its location. This project uses an Arduino microcontroller to connect various peripheral devices [19, 20, 21, 22, 23, 24,25, 26]. The system monitors constantly the vehicle and determine the local area of the vehicle upon request in real-time. Many control and tracking systems were designed to help persons or companies with a large number of vehicles. Those systems can manage and reduce the cost and effort of the police staff, in the case that a vehicle was stolen, within a short period of time. What differentiates this system is real-time tracking and feedback.

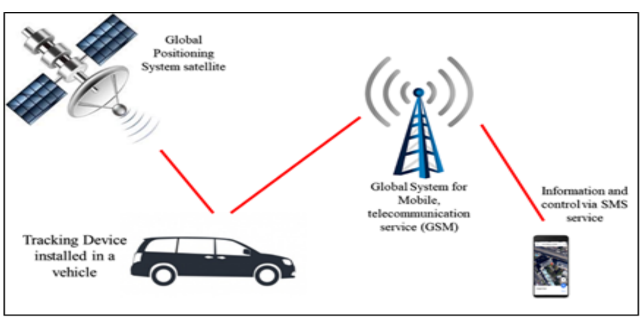


Fig 1. System Idea.

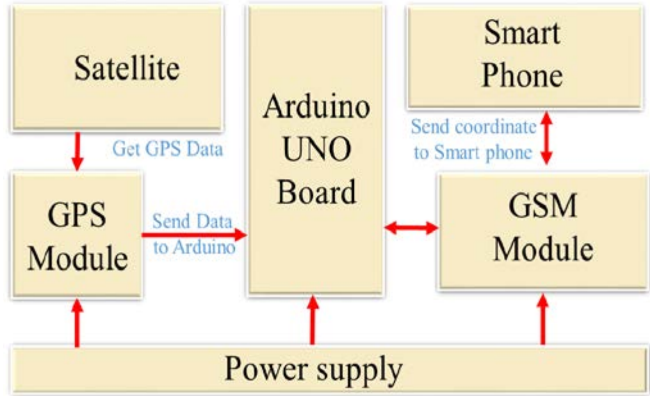


Fig 2. System Architecture.

The use of SMS applications has become popular because it is affordable, effective, convenient and easy to access, for transmitting and receiving data with high reliability [27, 28]. Therefore, this technology will be used in the current system, as illustrated in Fig. 1.

The system relies on a GPS receiver, modem GSM, and the as depicted in Fig. 2. The users can control, monitor, and interact with the vehicle from a dedicated application, as well as via Google Maps. Consequently, they can perform several actions through the vehicle, if it was stolen.

The system needs verification of the cellular phone number of the incoming message, to make sure that it is the owner's phone number, because it will use the Subscriber Identity Modules (SIM) phone number to authenticate the authorized person. If someone mistakenly sends a short message SMS to this system, she/he cannot receive any reply [29]. It would also be possible to contact the owner of the vehicle through a GSM kit with a portable computer to track the vehicle in real-time using Google Maps.

IV. System Implementation, Testing and Results

A. Hardware Implementations

The system can be run through a PC via direct connection or by connecting batteries directly to the system, as shown in Fig. 3.

Fig 3. Finial Implementation of the System.

B. Connect the GSM with Arduino

At this step, the connection between the GSM and Arduino is made using the kit connector which is designed to connect between two different shields, as shown in Fig. 4.

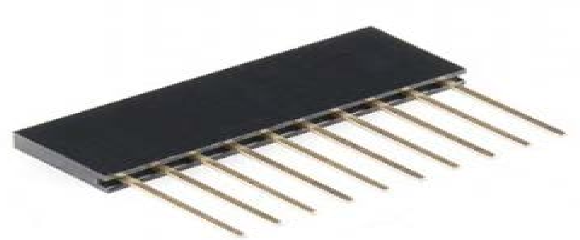


Fig 4. Kit Connector.

It must be fixed to the connector by the *"GSM"* to *"GPR Shield"*, which indicates each pin that specified in the table as shown below in four parts.

C. Electrical Connection

The digital connection alongside Arduino requires a corresponding pin for GSM, which is on the right side, as shown in Fig. 5. It can be noticed that there exists a connection between two shields, namely pin 7 in Arduino corresponds to D7 for GSM.

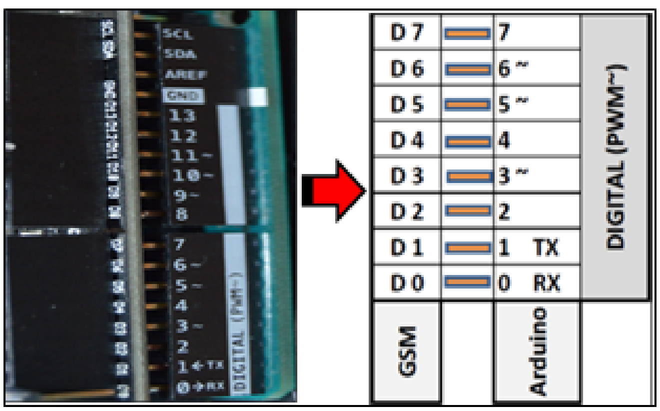


Fig 5. Connection between GSM and Arduino DIGITAL (PWM~).

D. Arduino ANALOG IN

The analog connection is alongside Arduino. Each pin of GSM is matched, as shown in Fig. 6. The connections between two shields are inversely related: for example, A5 pin in Arduino corresponds to A0 in the shield.

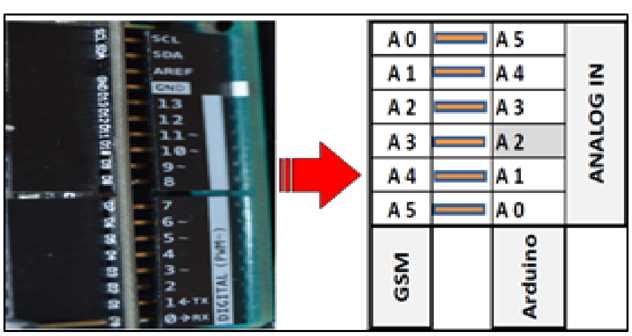


Fig 6. Connect GSM to the Arduino ANALOG IN.

E. Power

The system works by depending on the vehicle battery or the battery attached to it, the portable one, in the case if the vehicle's battery fails [3]. The power connection alongside with Arduino is required. Each pin of the GSM is matched as in Fig. 7, where the symmetry connections between two shields can be observed.

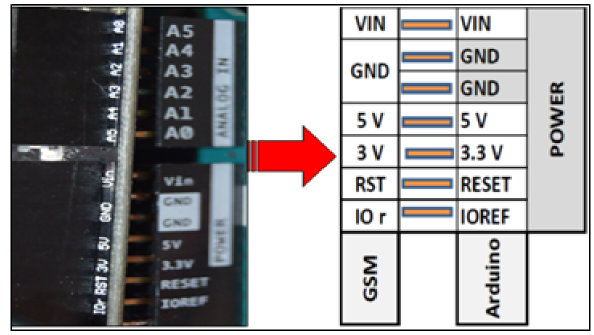


Fig 7. Connect GSM to the Arduino POWER.

F. Board Connection with Multiplexer

The circuit connection contains LEDs and a multiplexer to indicate all actions, as shown in Fig. 8. This board connects to Arduino along with cables.

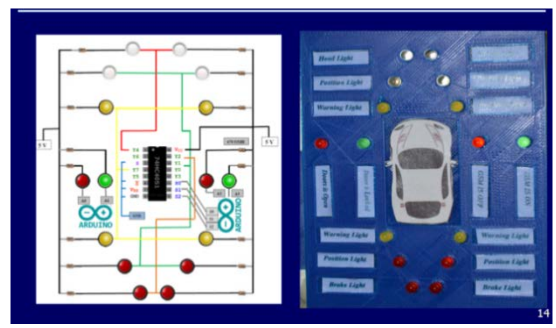


Fig 8. Circuit Diagram Control Box.

G. Connection between GPS and Arduino

The connection between GPS and Arduino is done using the steps 1 and 2 from Fig. 9, and through the RX and TX pins, corresponding to steps 3 and 4.

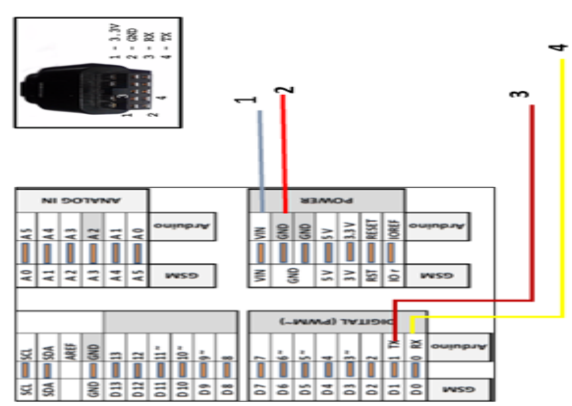


Fig 9. Connection between GPS and Arduino.

TABLE I. ACTION TABLE FOR THE VEHICLE SYSTEM

Action	Stats	white	Red	Yellow	Green
Turn on the scene light of car	ON	2	2		
Turn off the scene light of car	OFF	2	2		
Turn on the front light of car	ON	2			
Turn off the front light of car	OFF	2			
Turn on the brake light of car	ON		2		
Turn off the brake light of car	OFF		2		
Turn on the flashing light of car	ON			4	
Turn off the flashing light of car	OFF			4	
Closed the doors of the car	ON				1
Normal status the door is open	ON		1		
GSM is on after 60 second	ON				1
GSM of off when the system is start	ON		1		

The procedure listed in the Table I shown shows the LEDs indicators and correspondent action which is performed in the project.

V. SOFTWARE IMPLEMENTATION

A. Initialize

In the initialization procedure, first it is included the GSM and TinyGPS library; then it determines the GPS connection and SIM card number, and configures the library as shown in the figure. An array is defined to hold the number of "SMS" that will be received and shows the sender's number. Then a message from a phone is received - the message corresponds to an action that is going to be performed

B. The Definition of Multiplexer Pin

The definition of S0, S1, and S2 along with 10, 11, and 12 to make the action that is needed on the board and specify the second action that works when the system starts (ON):

- The red *"LED"* - waiting; *"GSM"* is not active
- The Green *"LED":* the "GSM" is active (wait approximately 30 seconds to be active).

Standby time allows "*GSM*" to figure out the network it operates on and the usual time duration for a transmission from the cell phone. The procedures run automatically when the system starts. The system works properly if the red *"LED"* for the '*GSM'* does not change to the green *"LED"*. This means that the system is an error and cannot send any message to the system:

- The red "LED" ---- the doors are opened
- The Green *"LED"* ---- the doors are locked

C. Define the Commands

The programming commands for text messages that will be sent to the system must be specified, by making a matrix of letters for each message, for one particular action in the system. Herein, the user must be alerted to the nature and form of the message sent if it is in uppercase, lowercase letters, or even spaces between letters. Any text message (not identical to the messages installed in the system) will be ignored and therefore will not result in any apparent action, which gives the impression that the system does not work. Fig. 10 showing all the messages used in this system.

```
//define commands
char lights_on[]        = {'0','l','i','g','h','t','s',':','O','N'};
char lights_off[]       = {'1','l','i','g','h','t','s',':','O','F','F'};
char head_lights_on[]   = {'2','h','e','a','d',':','O','N'};
char head_lights_off[]  = {'3','h','e','a','d',':','O','F','F'};
char brake_lights_on[]  = {'4','b','r','a','k','e',':','O','N'};
char brake_lights_off[] = {'5','b','r','a','k','e',':','O','F','F'};
char warning_on[]       = {'6','w','a','r','n','i','n','g',':','O','N'};
char warning_off[]      = {'7','w','a','r','n','i','n','g',':','O','F','F'};
char location_on[]      = {'8','l','o','c','a','t','i','o','n',':','O','N'};
char location_off[]     = {'9','l','o','c','a','t','i','o','n',':','O','F','F'};
char doors_on[]         = {'+','d','o','o','r','s',':','O','N'};
char doors_off[]        = {'-','d','o','o','r','s',':','O','F','F'};
```

Fig 10. Definition the Commands.

D. The Definition of the Commands Length

Each command has a fixed length as shown in the code bellow

```
//define vector length
int length_lights_on    = 9;
int length_lights_off   = 10;
int length_head_on      = 7;
int length_head_off     = 8;
int length_brake_on     = 8;
// etc.
```

E. Initialize States of the System

The initial value of each feature and each *'LED'* in the initial state is OFF (in the case of a restart, the system will return all values in the initial state).

F. Loop Function of the System

Table II we give the correspondence between messages, correspondent action and function performed by multiplexer.

TABLE II. MESSAGE TEXT, ACTION, FUNCTION

Message Text	Actions	Function
0lights: ON	Turn on position lights	Multiplex(1.0.0)
1lights: OFF	Turn off position lights	Multiplex(1.0.1)
2head: ON	Turn on head lights	Multiplex(0.0.1)
3head: OFF	Turn off head lights	Multiplex(1.0.1)
4brake: ON	Turn on brake lights	Multiplex(0.1.0)
5brake: OFF	Turn off brake lights	Multiplex(1.0.1)
6warning: ON	Turn on warning lights	Multiplex(1.1.1)
7warning: OFF	Turn off warning lights	Multiplex(1.0.1)

G. Sending the Locations

"*Sending Location for the vehicle*" is a significant step in the project. Every moment the latitude and longitude of the system is sent such that we know where the vehicle is at any moment.

```
void get_locaton(bool newData2){
for (unsigned long start = millis();
millis() - start < 1000;)
{
while (Serial.available())
{
char c = Serial.read();
if (gps.encode(c));
newData2 = true;
}
}
if (newData2)
{
float flat, flon;
unsigned long age;
gps.f_get_position(&flat, &flon,
&age);
Serial.print("LAT=");
LAT = (flat ==
TinyGPS::GPS_INVALID_F_ANGLE ? 0.0 :
flat);
Serial.print(LAT, 6);
Serial.print(" LON=");
LON = (flon ==
TinyGPS::GPS_INVALID_F_ANGLE? 0.0:
flon);
Serial.print(LON, 6);
Serial.print(" SAT=");
SAT = gps.satellites() ==
TinyGPS::GPS_INVALID_SATELLITES ? 0:
gps.satellites();
Serial.print(SAT);
Serial.print(" PREC=");
Serial.println(gps.hdop() ==
TinyGPS::GPS_INVALID_HDOP ? 0 :
gps.hdop());
}
```

H. Sending Google link

The most important part of this project is to send a Google link to show the location of the car at any moment in real time. This is done by first invoking the previous step to do that and then use the longitude and latitude to bring them to a required format. An example is given bellow: '<u>https://www.google/maps/place/44.44212+26.04938/@44.44212,26.04938,17z/data=!3m1!4b1! 4m2! 3m1! 1s0x0: 0x0? hl = en</u>'.

By clicking on the link, we enable the Maps application to open in the smartphone to show the location for the vehicle. the code for sending the google link to SMS

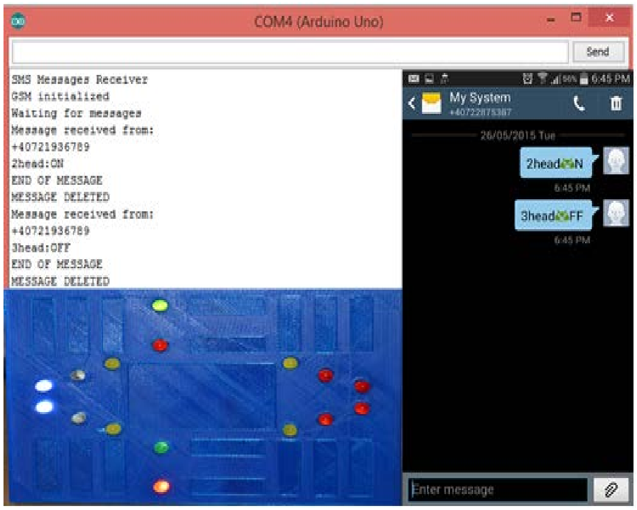
```
//https://www.google.ro/maps/place/44.44212+26.04938/@44.44212,26.04938,17z/data=!3m1!4b1!4m2!3m1!1s0x0:0x0?hl=en
if(send_google_maps == 1){
Serial.println("Acquire Location:");
get_locaton(newData);
//Composing the text for google the
message
txtMsg=
"https://www.google.ro/maps/place/";
dtostrf(LAT,6,6,LAT_buffer);
for(int i=0;i<=7;i++){
txtMsg= txtMsg + LAT_buffer[i];
}
txtMsg = txtMsg + "+";
dtostrf(LON,6,6,LON_buffer);
for(int i=0;i<=7;i++){
txtMsg= txtMsg + LON_buffer[i];
}
txtMsg = txtMsg + "/@";
for(int i=0;i<=7;i++){
txtMsg= txtMsg + LAT_buffer[i];
}
txtMsg = txtMsg + ",";
dtostrf(LON,6,6,LON_buffer);
for(int i=0;i<=7;i++){
txtMsg= txtMsg + LON_buffer[i];
}
txtMsg = txtMsg + ",17z/";
//Serial.println(txtMsg);
sendSMS();
send_google_maps = 0;
}
}
```

I. Testing the System

At this point, every "SMS" sent to the system will be tested for all actions that are needed to control the vehicle. The figures from 11-16 show the types and forms of messages that are sent, as well as show all the actions in the system, such as, turn on/off warning light. Moreover, all the processing (send and receive) messages that occur in the Arduino.

Turn on / off positions lights figure

Fig 11. Test the System ON/OFF Position Lights with Smartphone.

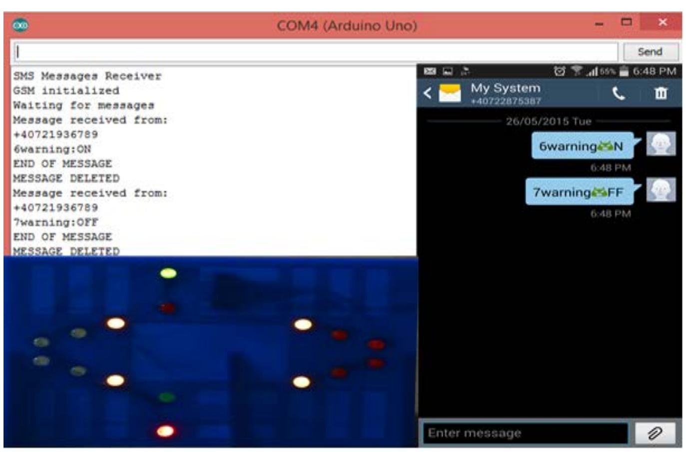


Turn on / off Headlights

Fig 12. Test the System ON / OFF Heads Lights with Smartphone.

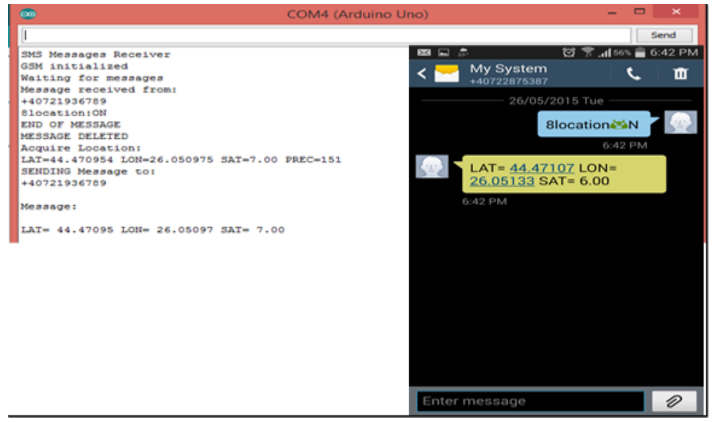
Turn on / off Brake lights

Fig 13. Test the System ON / OFF Brake Lights with Smartphone.



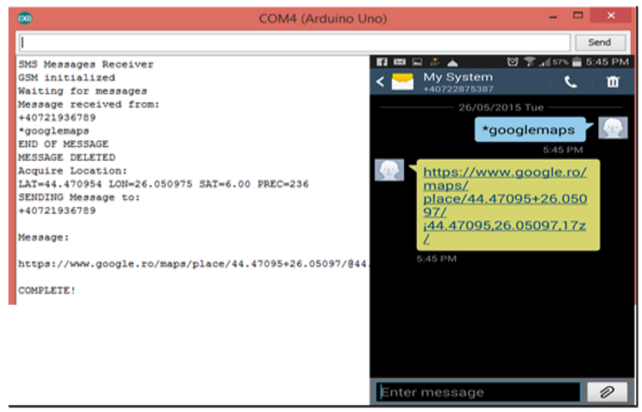
Turn on / off Warning lights

Fig 14. Test the System ON / OFF Warning Lights with Smartphone.



Send the Locations

Fig 15. Test the System Locations SMS with Smartphone.



Send the Google Maps Link

Fig 16. Test the System Google Link with Smartphone.

VI. The Result

For the control of the vehicle through this system to be implemented on the actual destination inside the car, we need to add other devices are (Riley) to support operations to be achieved actually inside the car.

The process of sending the message and execution of the request interspersed with some problems, including signal strength of the network that are working on the system (mobile phone network) where ensure signal strength speed of implementation of the system from the moment of sending the message to the moment of execution where it normally take this system from 4 to 6 seconds to interact with the message and implementation (in case the message was written correctly).

Sending text messages is incorrect will not give any reaction by the system, which gives the impression that the system does not function properly for this reason had to have interest in the message, as noted in previous chapters in this regard.

VII. Conclusion

The main objective of this system is to control of a vehicle and find out where it is in the case of theft. This system is made of several technologies including smartphone technology to find out the location area of the vehicle at a certain time. The system brings technology by using SMS text messages to reduce the costs resulting from the use of communication networks for mobile phones. It also uses several sources of power. This ensures system to work continuously in different conditions, even when the vehicle battery stops and gives reliability and independence to the system. Another important feature is the use of Google Maps.

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An Intelligent Approach for Detecting Palm Trees Diseases using Image Processing and Machine Learning

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***Abstract*—Today's palm trees diseases which cause a huge loss in production are extremely hard to detect either because these diseases are hidden inside the texture of the palm itself and cannot be seen by naked eyes or because it appears on its leaves which are hardly examined due to how far they really are from the ground. In this paper we're interested in detecting three of the most common diseases threatening palms today, Leaf Spots, Blight Spots and Red Palm Weevil. Diagnosis of these diseases are done by capturing normal and thermal images of palm trees then, image processing techniques were applied to the acquired images. Two classifiers were used, CNN to differentiate between Leaf Spots and Blight Spots diseases and SVM for Red Palm Weevil pest. The results for CNN and SVM algorithms showed a success rate of accuracy ratio 97.9% and 92.8% respectively, these results are considered to be the best results in this domain as far as we know. The paper also includes the first gathered thermal images dataset for palms infected with Red Palm Weevil and healthy palms as well.**

Keywords*—*Machine learning; deep learning; image processing; leaf spots; blight spots; red palm weevil

I. Introduction

There are more than 2,500 palm tree species which can produce over 1000 products [1]. This is why they're considered to be one of the most important trees all over the world. Palm trees play a crucial role in the agricultural economy of most of the country's int the Middle East as they are the top largest date producers in the world [2]. Top 10 Largest Date Producers in the World is shown in Table I. However, the quality and quantity of the palm trees are always at risk due to different types of diseases. Palm trees can be infected by two popular diseases such as Leaf Spots and Leaf Blights, these diseases vary in shape and size and are widely spread in palm trees farms leading to the essential need of investigating them [3].

Leaf spots symptoms appeared as small spread, irregular, brown to black which varies in size about 3-7 mm and appears on the upper and lower surface of rachis and fronds. [4]. Leaf blight symptoms appeared as elongated brown to black spots which enlarged on wide area causing cankers on the midrib [3]. Both symptoms of leaf spots and blight spots diseases are nearly the same and both of them appear on the palm tree leaves thus, detection of these disease are very challenging. One of the most important approaches to detect palm leaf diseases is the naked eye observation of experts which is expensive and requires continuous monitoring and will consume a lot of time especially in large farms.

TABLE I. Statistics Done by the Embassy of Egypt Economic and Commercial Office in Brazil, March 18, 2019 [2]

Top 10 Largest Date Producers in the World		
Rank	***Country***	***Production (1000 Metric Tons)***
1st	Egypt	1,373,57
2nd	Saudi Arabia	1,122,82
3rd	Iran	1,016,61
4th	United Arab Emirates	900,00
5th	Algeria	690,00
6th	Iraq	619,18
7th	Pakistan	557,28
8th	Oman	268,01
9th	Tunisia	180.00
10th	Libya	165.95

Another serious risk is a lethal pest called red palm weevil. Red Palm Weevil has been discovered in more than fifty countries which is reported to be the most harmful and destructive pest for palms [5] incurring a significant amount of economic loss [6]. Also, the yearly damages of approximately US $26 million was estimated in the Middle East plantations of date palm that was caused by RPW alone [7]. This pest develops deep inside the palm, hides in its texture and cannot be seen by the naked eye, destroying the vascular system of the palm and eventually leading to its death [8]. Recently In 2018, A new approach was invented to detect the red palm weevil by sensitive sensors but according to Dr. Kareem Shaarawy an agriculture engineer in Palm Research Center in Egypt; it is hard to get these sensors because they are expensive(about 1841 USD) and using them is complicated because detection of RPW in each palm tree requires the user to wait for 1 minute while holding the sensor to take the vibration readings inside the palm tree itself, not to mention the damage resulting from using such approach to the palm as it leaves a hole which can attract more insects and pests later on. In this paper, we provide an android mobile application with a Real-time detection of the

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common diseases mentioned before by mobile cameras and also Red Palm Weevil by acquiring thermal images of palm trees using thermal camera connected to smartphones. These images will be enhanced, then machine learning techniques will be applied to them in order to early detect these diseases before the palm reaches an untreatable state and without damaging the palm tree.

In this work, a novel intelligent method is proposed to detect three of the most common diseases threatening palms today. These diseases are namely, leaf spots, blight spots and red palm weevil (RPW). Diagnosis of these diseases are carried out by capturing normal and thermal images of palm trees. Then, image processing techniques were applied to the acquired images. Then CNN classifier is used to differentiate between leaf spots and blight spots diseases and SVM for detecting RPW pest. The results for CNN and SVM algorithms showed accuracy ratio 97.9% and 92.8%, respectively. According to our knowledge, there are currently scarce papers to tackle this issue using machine and deep learning techniques. Also, according to our knowledge, these results are the best results in this field so far.

The rest of this paper is organized as follows: Section II presents some related works in this domain. Section III will justify both CNN and SVM algorithm which are used in the proposed system. Section IV is devoted to introduce the proposed model. Section V will show the experiments done and their outcome results. Finally, we summarize the conclusion of the paper in Section VI.

II. Related Work

This section explains the literature review that is concerned with the same domain. Related works are divided into two subsections. One for detection of leaf spots and blight spots disease and the other for detection of RPW.

A. *Detection of Plants Leaves Diseases*

In [9], the author aimed to detect leaf blight disease in tomatoes leaves by using CNN and with LVQ classification Algorithms. The bacterial spot, late blight, septoria leaf spot and yellow curved leaf diseases are the classes used in this experiment. The dataset consists of 400 training and 100 test tomato leaf images used from a plant village dataset. The images in the selected dataset have been cropped to the size of 512x512. To achieve better results, different color components were used instead of using a single one. 20 images for every classes were used to test the model including a healthy class, a few numbers of the images were inaccurately classified, four of them are for leaf diseases and one of them is for healthy leaves. This model achieved an accuracy of 86%. One of the main challenges in disease detection and classification for this study is that the leaves are infected with different diseases which are very similar to each other.

In [10], a real-time detection of brown spot apple leaf disease using deep learning approach is presented. Alternaria leaf spot, Brown spot, Mosaic, Grey spot, and Rust are five common types of apple leaf diseases are used as classes in this study. A new apple leaf disease detection model was created using deep-CNN algorithm. Moreover, a new deep-learning-based approach, namely, INAR-SSD was used and implemented by Caffe framework on the GPU platform using a dataset of 26,377 images of diseased leaves. For the image annotation, an algorithm that provides a frame selection function was used along with the knowledge provided by experts in the field of agriculture so that the diseased areas of an image were successfully selected and labeled with the corresponding classes. The comprehensive detection performance reaches 78.80% mAP and speed of the model reaches 23.13 FPS.

In [11], Chimaera and Anthracnose diseases in palm oil tree were detected using image processing techniques. The symptoms of Chimaera disease are confined to the palms' leaves having white or yellowish-white stripe, and the lack of chlorophyll in them. The severity of the Anthracnose disease lies in the possibility of affecting all palm oil trees at any of their growth stages. Images were acquired using a digital camera then processed using matlab. The images' intensity values or colour map were adjusted as part of the image enhancement phase. Adding to this, the image segmentation which consisted of a colourbased segmentation using k-means clustering by converting the image from RGB to L*a*b colour. Eventually feature extraction process took place and gyrocomatrix was used to create the graylevel cooccurrence matrix (GLCM) from the image, by using this technique the image texture and colour were considered to come out with the features that represented the image. By going through these processes, the presence of diseases on the palm oil leaf was successfully identified. Proving the success of the support vector machine (SVM) classifier in such cases showing an accuracy of 97% for Chimaera and 95% for Anthracnose.

B. *Detection of RPW using Thermal Imaging*

Thermal Imaging is known to be used in reporting heat exchange of plant leaf, their water stress and their transpiration rate [12]. Accordingly, it is recommended to be used in detecting RPW which destroys the vascular system of the palm trees, creates water stress and affects canopy temperature [13, 14].

In [15], an uncooled infrared thermal camera attached with a microbolometer sensor was used to capture the images. Six experiments were carried out, including Canary and date palm trees. Each experiment contained 4-5 duplicates of control trees and 8-10 duplicates of infested trees. ThermaCAM Researcher software was used to process the collected images. This software was provided with the local environmental conditions and the leaf emissivity in order to produce reliable leaf temperature maps. Furthermore, Crop Water Stress Index (CWSI) was calculated and used to assess the water stress induced by RPW inside the palm trees [16]. It was then noticed that infected trees showed higher temperature rates and higher CWSI values than controlled ones. From eight known infected trees, six were correctly identified as infected (accuracy of 75 %).

In [17] an uncooled infrared thermal camera and a microbolometer attached to it was used to capture aerial images. The flight height was 760–770m above the ground. The goal of their experiment was to distinguish palm trees from soil based on their water stress and temperature rates. Three date palms were included in the experiment and are irritated with known quantity. Using image processing, they did split the palm canopy from soil and a watershed algorithm was applied to the images in order to outline the palm canopy [18]. Since temperature of the canopy is lower than that of the soil, Nmax pixels was determined and according to a temperature threshold the canopy was detected, this temperature threshold was determined by Otsu method [19]. The study proves that it is possible to differentiate between water stress of different palm trees, which can be useful to distinguish between healthy palm trees and those infected by RPW.

III. Preliminaries

A. Convolutional Neural Network(CNN)

CNN is based on neural network of the human brain and consist of multiple layers. The first layer is the convolutional layer, also called the input layer and is described by equation (1) as follows:

$$input = n_h^{(L-1)} * n_w^{(L-1)} * n_c^{(L-1)} \tag{1}$$

Input layer consists of filters that are optimized according to the problem that’s being solved. For each convolutional layer, there are multiple kernels stacked on top of each other, this is what forms the 3-dimensional matrix for each kernel, we have its respective bias described by equation (2) as follows:

$$Bias = 1 * 1 * 1 * n_c^{(L)} \tag{2}$$

Thereafter, an output for this layer, the green matrix in Fig. 1, which has dimensions [h * w *d]. Where d is the depth and h is the height and w is the width of the matrix respectively. The filters depth change and for each position of the kernel on the image, each number on the kernel gets multiplied with the corresponding number from the input matrix and then all are summed up for the value in the corresponding position in the output matrix with the depth of the input matrix >1, the same applies for each of the channels and then they are added up together with the bias of the respective filter as well and this forms the value in corresponding position of the output matrix shaping the depth of the output layer. This entire process is repeated and it’s described by the equation (3) as follows:

$$EachFilter = f^{(L)} * f^{(L)} * n_c^{(L-1)} \tag{3}$$

with all the d2 kernels which forms the d2 channels in the output layer which is described by equation (4) as follows:

$$Output = n_h^{(L)} * n_w^{(L} * n_c^{(L)} \tag{4}$$

Another layer is the poling layer which has two types; max pooling and average pooling. The main purpose of a pooling layer is to reduce the number of parameters of the input tensor and thus, helps reduce overfitting [20]. Extracting representative features from the input tensor and reducing computation is also one of its utilizations and thus aids efficiency in max pooling case. The layer moves according to the kernel size choosing the maximum value in the matrix. On the other hand, the average pooling chooses the average value then all of the CNN is connected with a flatten layer which connects the convolutional layers with the dense layer (output layer) and usually the network stop learning when it gets the optimal weights [21] which is outlined by equation (5) as follows:

$$Weights = f^{(L)} * f^{(L)} * n_c^{(L-1)} * n_c^{(L)} \tag{5}$$

B. Support Vector Machine (SVM)

SVM is a supervised learning model which can be used to solve classification and regression that makes it efficient in solving problems in general. Classification in the SVM is done by creating a divider between classes the divider is called a hyperplane also known as decision Boundary which helps the SVM to take decisions. The reason that makes the SVM popular is its use in kernelization [22] and because it is versatile. It can also work for multiple classes and it can work for multi linear problems too. We can get the hyperplane of Fig. 2 using the equation (6) after calculating multiple decision boundary and choosing the right one then we can classify [23]. as follows:

$$W^t X = 0 \tag{6}$$

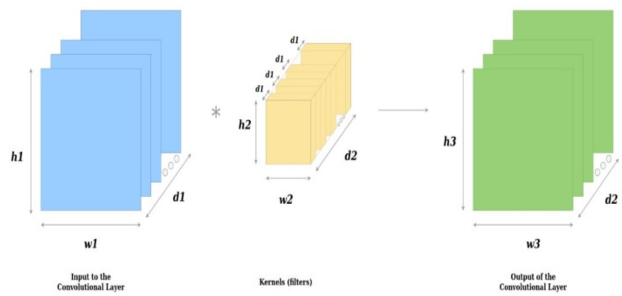


Fig. 1. Convolutional Layer.

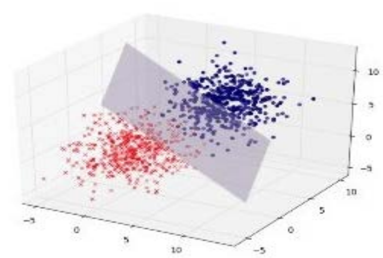


Fig. 2. SVM Hyperplane.

IV. The Proposed Model

Fig. 3 shows the flow chart of the proposed model. The model starts with the image acquisition phase. In this phase images are acquired either using normal mobile camera for leaves diseases like leaf spots and blight spots or by using thermal camera for detecting RPW inside palms trunk. In the input phase, The Acquired images is enhanced then features are extracted so the model can train and classify disease in the output phase then finally showing the results to the user.

A. Data Acquisition

Since we're dealing with two different types of diseases, one is leaf-based and the other is pest-based and because of their different features, separate datasets were constructed as follows:

1) Leaves dataset (Leaf-based): The dataset is acquired from a well-known website (Kaggle), it contains a total of 91,360 images for leaf spots and blight spots diseases. Using the dataset as is resulted in an unsatisfying performance of our model because of the low variation of the images. Therefore, the augmented data set was analyzed to get the original images before augmentation leading to the selection of 35 leaf spots images and another 40 images for blight spots adding to this 50 more palm images that we collected for each disease using a Samsung Galaxy A50 mobile camera of 25Mp sensor with 26mm-equivalent f/1.7 lens. Moreover, since the original images of the Kaggle's dataset were too big in which they contained too much unwanted information that caused a downgrade in the image quality when resizing to our 224*224 input image size, the regions of interest (infected parts) were manually cropped to a certain scale that is divisible by 224*224 in order to preserve as much information as possible in the image. Afterwards, the images were resized to our input size and image augmentation techniques which are rotation, flipping Fig. 4, Fig. 5, and adjusted different brightness Fig. 6, Fig. 7 values were applied resulting in 5250 images for each disease. Another challenge were tackled right after applying rotation on images, images were having a black background that caused some sort of noise and also extra unwanted signals, so the black background was removed and converted to a transparent one by adding an alpha channel to remove the noise Fig. 8, Fig. 9.

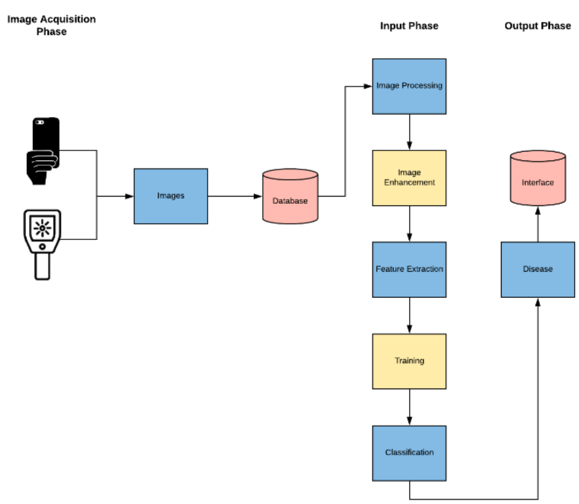


Fig. 3. Proposed System Overview.

Fig. 4. Before Flipping.

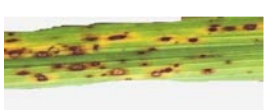


Fig. 5. After Flipping.

Fig. 6. Low Brightness.

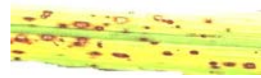


Fig. 7. High Brightness.

Fig. 8. Image with Noise.

Fig. 9. Image without Noise.

2) Red Palm Weevil dataset (Pest-based): A thermal images dataset was built and classified into two classes; healthy palms and palms infected with RPW. The healthy class contains 16 images and the infected class contains 24 images which were acquired at different times (12 pm and 10 pm) from Palm tree from Palm Research Center in Giza government in Egypt with a Testo 890-2 thermal camera. Due to COVID-19 pandemic, it was hard to gather more images, therefore augmentation techniques were used to increase the number of images to 1200 images for each class.

B. Feature Extraction

This part is mainly dedicated to the SVM model which predicts whether the palm is infected by Red Palm Weevil or not from their thermal images. Since infrared thermography offers a digitized thermal distribution called thermograph, the analysis of thermal images becomes more beneficial after extracting signals and information stored in them. Thermal images contain two types of features which are textural and statistical features. Texture feature measure the relationship among the pixels in local area, reflecting the changes of image gray levels [24]. This is why the images were converted to grey scale so that their Gray-Level Co-Occurrence Matrix (GLCM) properties can be used in feature extraction. In order to mimic the way of feature extraction used in deep learning models like CNN; back propagation and variation of filters were used to put all the possible combinations of features to get the most out of the image and get the best out of the model.

C. Classifications

CNN and SVM classifiers were selected for detecting common diseases and RPW infected palms respectively as they are considered to be the top classifiers known to accomplish such work efficiently [25], [26], [27]. CNN was preferred to be used in the common diseases case due to the size of our dataset described in Section IV-B. Similarly, SVM was used in identifying RPW infection because the dataset was too small

[28]. Proposed CNN model is built on pre-structured VGG16 Network that's known for its well measured layers and hyper-parameters and ensures efficient feature extraction and learning processes. Customization was made in some layers in the VGG16 architecture to fit our common diseases classification case by adding two call backs to the model; early stopping, and model check point. Early Stopping call back was to help the model stop when no more convergence happens in training and model check point needed to save the best model in the training process. VGG16 showed better results than our planned CNN model as the structure of VGG16 was more suitable than our planned CNN model, which shown in Table II. Also, some features were added to get the mean of the image, contrast between image pixels and standard deviation inside a matrix that makes it computationally inexpensive, efficiently extracting features and predicting the outcomes in a maximum accuracy depending on the variation and the size of the given dataset.

TABLE II. STRUCTURE OF VGG16 AND THE PROPOSED CNN MODEL

Hyper Parameters	***VGG16***	***Proposed CNN Model***
Convolutional Layers	13	7
Max Pooling Layers	5	3
Dropout Layer value	0.1	NaN
Activation function	Softmax	Softmax
Train Split	0.8	0.7
Test Split	0.2	0.3
Train Batch Size	120	32
Test Batch Size	30	32
Epochs	6	124
Call Backs	Early Stopping/ Model Checkpoint	NaN
Early Stopping Patience	5	NaN

V. RESULTS AND DISCUSSIONS

Kaggle's dataset was used as is (more than 90k images), leading to an achieved accuracy of 65% by the first CNN model. Dataset was divided into 70% for training and 30% for testing. The results of this model regarding blight spot disease showed overfitting. This affected the model by reducing its predictive power not forgetting the disappointing results when it comes to the detection of leaf spots disease Fig. 10 and Table III. The results were improved in the second CNN model after applying the image enhancements and by providing the dataset with a precisely chosen group of images for both diseases. The second model successfully achieved an accuracy of 97.9% and a prediction hit ratio of 9 to 10 on just about 10.5k images (80% training and 20% testing) solving the overfitting problem for blight spot disease and improving leaf spots detection results significantly Fig. 11 and Table IV.

On the other hand, our SVM model is built upon scikitlearn library, LinearSVC algorithm was preferred because it is the best one to fit our case due to its efficient way of classifying [27]. This worked well with an accuracy of 93% and a prediction hit ratio of 18 out of 18 healthy images, and 4 out of 5 infected images.

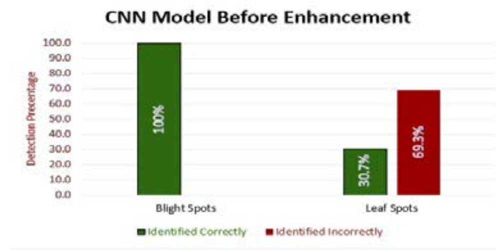


Fig. 10. CNN Model before Enhancements.

TABLE III. CNN RESULTS BEFORE ENHANCEMENTS

Diseases	***Precision***	***Recall***	***F1-Score***
Leaf Spots	1.00	0.31	0.47
Blight Spots	0.59	1.00	0.74

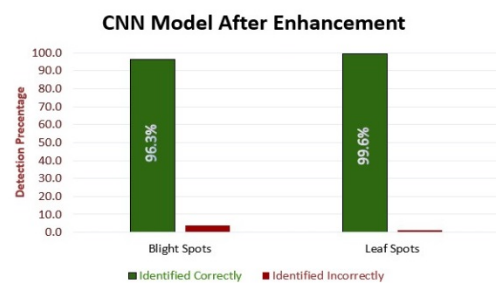


Fig. 11. CNN Model after Enhancements.

TABLE IV. CNN RESULTS AFTER ENHANCEMENTS

Diseases	***Precision***	***Recall***	***F1-Score***
Leaf Spots	0.96	1.00	0.98
Blight Spots	1.00	0.96	0.98

Also, two different experiments, one for the CNN model detecting leaf and blight spots diseases and the other for the SVM model differentiating RPW infected palms from healthy ones.

a) Experiment (1): Objective: proving the CNN model's ability to detect leaf spots and blight spots diseases at different circumstances. Therefore, normal mobile camera was used in collecting images during day time, with no filter added but, at night the camera's flash light was used. Adding to this, that these images were collected at different distances from the palm.

Setup: images were captured by two different mobile cameras. For leaf spots, Samsung galaxy S9 camera was used and for blight spots, Huawei nova 3e camera was used. The experiment includes two different palms; One palm is infected with leaf spots disease shown in Fig. 12 and the other palm is infected with blight spots disease shown in Fig. 13. A total of 8 images were acquired. For each palm, four images were captured, two of them at daytime(1pm-2pm) with no filter added and the other two at night(9pm-10pm) using the camera's flash light. The difference between the two images at each time period is the distance from the palm, as one of the images were closer to the palm than the other. Table V contains the CNN results of palm1. Table VI contains the CNN results of palm2.

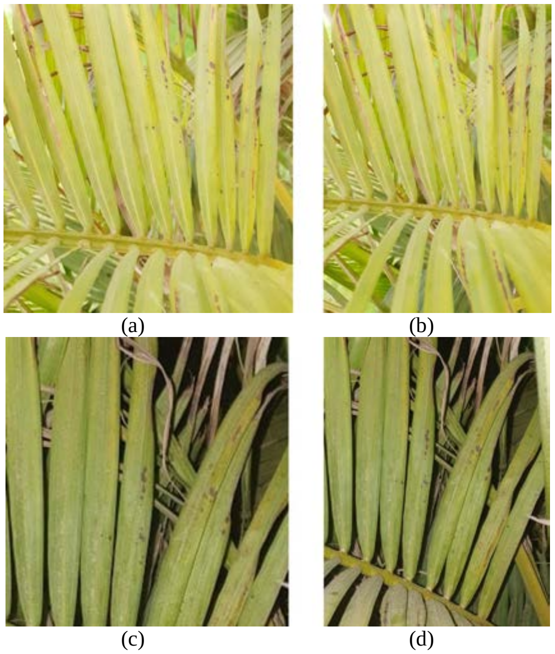


Fig. 12. Palm 1 Leaf Spots.

TABLE V. CNN MODEL RESULTS FOR PALM 1

Leaf Spots Images Results		
Palm	***Time/Distance***	***Predicted***
a	Daytime/Near	Leaf spots
b	Daytime/Far	Leaf spots
c	Night/Near	Leaf spots
d	Night/Far	Leaf spots

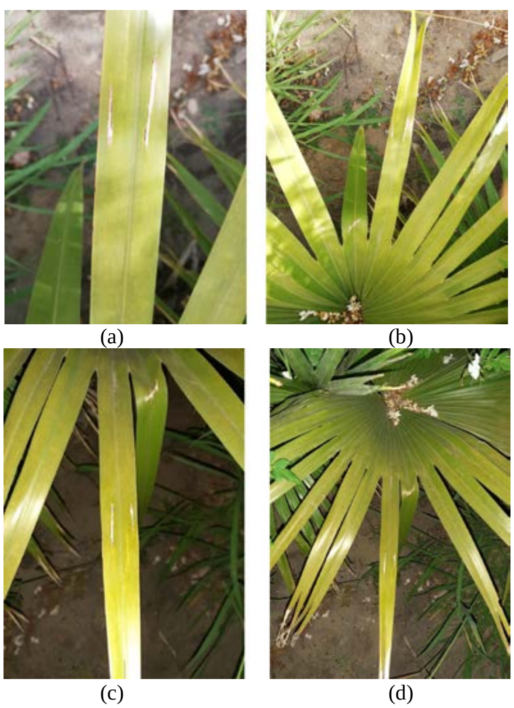


Fig. 13. Palm 2 Blight Spots.

TABLE VI. CNN MODEL RESULTS FOR PALM 2

Blight Spots Images Results		
Palm	***Time/Distance***	***Predicted***
a	Daytime/Near	Blight spots
b	Daytime/Far	Blight spots
c	Night/Near	Blight spots
d	Night/Far	Blight spots

CNN model showed successful results by identifying all of the given 8 images correctly. This experiment shows that the model can detect Leaf and blight spots diseases not only at day time but also at night using flash camera and at different distances from the palm.

b) Experiment (2): Objective: RPW changes the temperature of the palm tree which is why we decided to use thermal cameras in the first place and since the radiation of the sun is considered one factor affecting palm's temperature, examining the model at different time periods throughout the day can be deceitful for the SVM model built but is a challenge to prove the success of our suggested model. Thus, at this part we are going to test only healthy palms at day time and also different periods of time in anticipation of any absorption of the sun's heat energy by the palm. Evaluating the SVM model to detect the palms infected with RPW will be clarified in the second part of the experiment.

Setup: For the first part of the experiment, images of healthy palms were captured using FLIR one pro usb portable camera attached to a mobile phone through FLIR ONE application. In Fig. 14, three images were acquired for a palm tree at different time periods (1pm, 5pm, and 9pm). Table VII presents the SVM model results for healthy palm. For the second part, images of infected palms were captured using the same camera but this time the camera is attached to a tablet though using Vernier application. In Fig. 15, three images were acquired for three different palms and were carried out between (12pm and 1pm). Table VIII presents the SVM model results for infected palm.

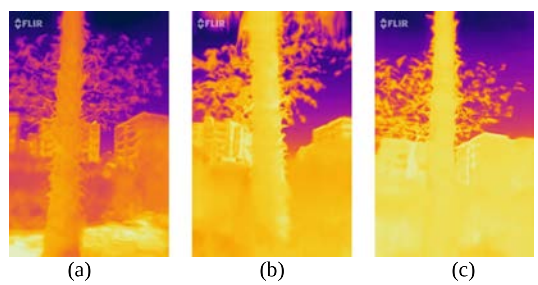
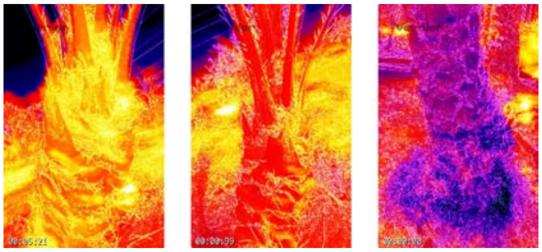


Fig. 14. Healthy Palm Thermal Images.

TABLE VII. SVM MODEL RESULTS FOR HEALTHY PALM

Healthy Images Results		
Palm	***Time***	***Predicted***
a	1pm	Healthy
b	5pm	Healthy
c	9pm	Healthy



(a) (b) (c)

Fig. 15. Infected Palms Thermal Images.

TABLE VIII. SVM MODEL RESULTS FOR INFECTED PALMS

Infected Palms Results	
Palm	***Predicted***
a	Infected by RPW
b	Infected by RPW
c	Infected by RPW

SVM model showed successful results by identifying healthy palms in different time periods despite the heat energy that maybe preserved by the palm and affecting its temperature due to the sun's radiation. The model succeeded in identifying all of the healthy images as well as the palms infected with RPW. This experiment proves that thermal imaging is a reliable method for detecting RPW pests inside palm trees.

VI. CONCLUSION

In this work, image processing and machine learning techniques were applied to develop an application that can detect palm tree common diseases such as leaf spots and blight spots and red palm weevil lethal pest. For leaf spots and blight spots a dataset of total 5250 images were used for each disease. A VGG convolutional neural network algorithm was applied for classification, achieving a success rate of 97.9%. For red palm weevil pest, thermal images were used for infected palm trees. The dataset used was 1200 thermal images for healthy palms and another 1200 thermal images for palm trees infected with RPW. SVM model was built upon scikit-learn library, LinearSVC algorithm was used as the classification algorithm, which achieved a success rate of 92.8%. RPW is attracted to the wounds of the palms if found and since thermal imaging has no side effects on the palms health it is considered one of the best methods used so far.

VII. FUTURE WORK

Thermal imaging can be used continuously to ensure regular monitoring on large number of palms which makes this method cost-effective and can also give satisfactory accuracy and reliability through aerial thermal imaging before visual symptoms of the RPW is observed on the palms canopy, for the meantime we couldn't get a drown or use satellite imagery due to security reasons in our country but we aim in the future to use one of them for aerial imaging. Another promising method for detecting RPW is hyperspectral imaging. Although it is a complex and expensive method but it shows very high accuracy detection as some studies showed [29], [30], [31] and deserves consideration. Also, swarm intelligence algorithms can be used to enhance and optimize both SVM and CNN. Finally, we aim to collect more images for our dataset images because there are limited number of images available in this research domain.

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Entropy-Based k Shortest-Path Routing for Motorcycles: A Simulated Case Study in Jakarta

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***Abstract*—Traffic congestion is a serious problem in rapidly developing urban areas like Jakarta, Indonesia's capital city. To avoid the congestion, motorcycles assisted with navigation apps are popular solution. However, the existing navigation apps do not take into account traffic data. This paper proposes an open-source navigation app for motorcycle by taking into account the traffic data and wide road to avoid congestion. The propose navigation app uses entropy-balanced k shortest paths (EBkSP) algorithm to suggest different routes to different users to prevent further congestion. Tests show that the proposed route planning system in the app gives routes that are significantly shorter than motorcycle routes planned by Google Maps. The EBkSP algorithm also distributes vehicles more evenly among routes than the random kSP algorithm and does so in a practical amount of computing time.**

Keywords—Traffic congestion; motorcycle; navigation apps; EBkSP

I. Introduction

The transportation sector has a great influence on development across all other sectors of an economy. In Jakarta, the capital city of Indonesia, as many as 3.5 million people used ground transportation infrastructure to travel to work or school in 2014. Private vehicles are still the favoured means of transportation because Jakarta's public transit architecture is not fully developed. Jakarta has 3.3 million cars and 13 million motorcycles, and these numbers grow by approximately 8%–10% annually [1]. With road capacity increasing by less than 1% each year, the number of vehicles will eventually exceed the available road capacity. In 2014, the ratio of road surface to the number of cars/motorcycles in Jakarta was 3:1, meaning that for every 3 m^2 of road, at least one car or motorcycle was in the city [2].

Motorcycles are very popular in Jakarta for their relatively low price and their manoeuvrability on narrow roads. Motorcyclists can avoid traffic congestion by taking shortcuts that are inaccessible by car. However, many motorcyclists do not have access to a navigation system that shows such shortcuts. With the number of motorcycles in Jakarta almost four times the number of cars, open-source navigation apps intended specifically for motorcyclists are in high demand. Moreover, such an app has the potential to reduce congestion for all vehicles in urban areas by distributing motorcycle traffic away from wider roads.

Navigation apps collect traffic and map data and plan the shortest route between two points using some algorithm. The entropy-balanced k shortest paths (EBkSP) routing algorithm is promising for this purpose and has been shown to be effective in urban environments [3]. The existing navigation apps, such as: Bing Maps and Apple Maps, do not have navigation for motorcycle. There is only Google Maps that provides the navigation for motorcycle. This paper compares performance of proposed apps with the routing with Google Maps. This paper presents a case study of the effectiveness of this algorithm in a motorcyclist-specific navigation system that is simulated using a primary data. The route-planning tests were conducted by a field trial of origin-destination (OD) pairs in 6 (six) sub-districts in Jakarta, Indonesia.

The navigation system presented below uses open-source data and libraries for route planning, and the case study shows that the EBkSP algorithm effectively distributes vehicles among the shortest routes between two points to reduce the navigation app's chances of making congestion worse. The results suggest that a motorcyclist-specific navigation app would be useful in cities like Jakarta, and that EBkSP is a promising strategy for navigation apps that do not concentrate users on suggested routes.

The rest of this paper is organized as follows. Section 2 reviews the literature on route planning to introduce the available algorithms and clarify how the constraints presented by Jakarta's environment indicate demand for a novel open-source navigation system. Section 3 formulates the EBkSP algorithm and outlines the software architecture we used to test it. Section 4 presents the data and map used for route-planning tests. Section 5 presents the test results and compares the performance of the motorcycle-specific EBkSP route planner against similar planners. The route planners are compared in terms of the lengths of routes they suggest, the distribution of vehicles on those routes, and the computation time needed for route planning. Section 6 briefly draws conclusions that highlight the promise of an open-source entropy-based navigation system that considers paths specifically for motorcyclists.

II. Related Works

The literature on navigation apps includes a variety of approaches for collecting traffic data and detecting congestion. Global Positioning System (GPS) location services can be used along with real-time traffic data, such as in the MobiWay app, which also implements Long Short-Term Memory networks. Vehicular ad hoc networks (VANETs) can also be used to quantify road traffic congestion in a distributed manner in an environment with sufficient penetration of connected vehicles. Still others have used data from GPS location services and VANETs simultaneously [4-9]. For an app that can be used in Jakarta, traffic congestion is best detected from vehicle speeds using GPS location data collected from user smartphones. This speed data can then be processed using Kalman Filtering to detect traffic congestion [10].

Route planning is then needed to direct users around traffic congestion. Google Maps and Waze are popular smartphone apps that give users the shortest route to a destination along with alternate routes and estimated travel times. These applications are very popular, and that popularity may actually exacerbate traffic congestion. If a very popular navigation app suggests the same route around a traffic jam to many users at once, that route will then become congested itself. Dynamic Traffic Assignment (DTA) takes account of temporal factors in route planning to ensure that route planning does not incidentally increase traffic congestion [11]. Vehicle to infrastructure (V2I) technology that relies on roadside units can be used to achieve DTA, such as in Congestion Avoidance through Traffic Classification Mechanism and Rerouting Algorithm (CHIMERA) [12], Next Road Rerouting (NRR) [13], and System with Cooperative Routing to Improve Traffic Condition (SCORPION) [14]. However, V2I technology cannot be applied in Jakarta because of its lacking road infrastructure and the lack of vehicles that can communicate with that infrastructure.

Studies have shown that EBkSP performs better than the dynamic shortest paths and random k shortest paths (RkSP) algorithms [15]. EBkSP looks for the shortest k routes and then recommends the most unpopular route to a user, and the popularity of each route is updated with each route-planning request. Simulations of traffic congestion have been shown to be useful in evaluating route-planning algorithms' ability to reduce congestion [16]. Navigation systems that collect data from road side units (RSUs) have also been tested in simulations, but these systems also cannot be implemented in Jakarta due to lacking infrastructure [17] [18] [19]. One study found that navigation systems that do not require RSUs still can overcome traffic congestion [20].

All of the navigation systems mentioned above are in the stage of simulation testing, so they are obviously not available to users. Other researchers have created a navigation app that uses Dijkstra's algorithm for route planning and takes advantage of data from RSUs [21]. The application was not designed for DTA, and cannot be applied with Jakarta's infrastructure. Navigation systems have been designed and tested using the open-source Simulation of Urban Mobility (SUMO) connected to the Google Maps application programming interface (API) for map and traffic data [22]. Another open-source option is to import maps from OpenStreetMap into PostgreSQL databases and use the pgRouting library for route planning [23]. We follow the latter strategy for testing the EBkSP algorithm's usefulness for motorcycle-specific routes. As we will explain in following sections, the algorithm and trial reported in this paper is the continuous development on integrated solution device for motorcycle [24].

III. The Algorithm

A. Algorithm Design

To plan routes specifically for motorcyclists, available map data needs to be reconfigured such that the route planner prioritises routes that are too narrow for cars to pass. We modify the road classes included in OpenStreetMap for this purpose. The map data is configured for motorcycles by modifying the configuration for bicycles and adding some wider roads routes that cars can use, though toll roads are still excluded. The resulting road classes in the map configuration for motorcyclists are as follows, sorted in order of increasing priority for route planning:

- Track (unpaved surface)
- Service (small shortcut to some roads)
- Living street (within residential areas, speeds are kept low)
- Residential (access to housing)
- Tertiary (link smaller towns and villages)
- Secondary (link towns)
- Primary (link larger towns)
- Trunk (divided highway)

The road classes above are written to an xml file that can be used by the osm2pgrouting library. The route planner will seek roads of higher priority first when plannign a route between two points.

For testing of the EBkSP route planner, we modify the k shortest paths (kSP) routing algorithm included in pgRouting to use entropy in the routing calculations. The kSP routing protocol searches for k alternate routes from the current point to a destination, which in this simulation are limited to three. The number of route options is limited to three for left, right, and continuing straight; if turning around is included the algorithm can get stuck in a loop.

The EBkSP routing algorithm the popularity of a route to avoid congestion on the route to be traversed. More popular routes are more likely to be congested congestion as vehicles clog the route. Algorithm 1 describes EBkSP in steps. The algorithm begins with the input of the user's origin and destination points. After receiving this information, the server calculates alternative routes based upon weighted footprint data. The weighted footprint data indicates the popularity of each route, and congestion can be prevented by directing users to unpopular routes that are of equal length to the shortest routes available. In practice, the weighted traffic footprint data would be collected from users that use the navigation app. For the sake of the present simulation tests, this footprint data was prepared manually.

Algorithm 1. EBkSP algorithm

Input:
Get device’s origin, destination
Collect all k paths
Collect weighted traffic data

Output:
Appropriate route

Procedure:
Analyse weighted traffic data
Choose shortest route
for not updated weighted traffic data
    if route chosen is least popular **then**
        Choose route
        Update weighted footprint data
    end if
    else if all routes equally popular **then**
        Choose route
        Update weighted footprint data
    end if
    else if eliminate shortest route **then**
        Choose next-shortest route
    end if
end

Equation (1) gives the popularity of route j as an exponential function of the entropy of route j. $Pop(p_j)$ takes the value of 0 if no car has taken j. The entropy of each route is calculated using equation (2), which sums the natural logarithms of the inverse of the number of vehicles heading in a given direction from some starting point, N, for each vehicle that has passed through route j, n_j.

$$Pop(p_j) = \begin{cases} e^{E(p_j)}, n_j \neq 0 \\ 0 \qquad , n_j = 0 \end{cases} \tag{1}$$

$$E(p_j) = -\sum_{t=1}^{n_j} \frac{1}{N} ln\ \frac{1}{N} \tag{2}$$

$$N = \sum_{t=1}^{n} n_j \tag{3}$$

If the routes are equally popular, the shortest route is chosen. If the routes have different levels of popularity, the server will choose the least popular route even if it is the longest. Once the route is selected, the user is assumed to follow the route, and the server will update the weighted footprint data. If we imagine a sequence of users requesting routes from the algorithm, the first user will be assigned the shortest route because all routes are equally popular before any user has taken them. The next user will be assigned the next-shortest route because the first user made the shortest route more popular than the rest. Through this process, the algorithm distributes vehicles evenly among all possible routes between two points if all vehicles follow the routes it suggests. We can record the average distance of the paths taken between two points in a traffic simulation to assess the effectiveness of this route-planning strategy.

B. Software Architecture

The present research is intended toward the design of a smartphone navigation app that motorcyclists can use in a city like Jakarta. The overall software architecture can use a centralized server for processing. The server has access to map and traffic data and presents a map to the user on his or her smartphone. The smartphone app then requests a route from the server based on user input. The server calculates the popularity of all routes and executes the algorithm, and then the results are displayed on the user's device as a route on the map.

C. Frontend and Backend Design

Frontend software interacts directly with the user. The variables required by the backend section are obtained from the frontend section, and the frontend also displays the output route in an image form that can be understood by the user. In a practical implementation of this navigation app, users would need to use a web application that can be accessed through a computer or a Hypertext Markup Language 5 (HTML5)-based application on a smartphone.

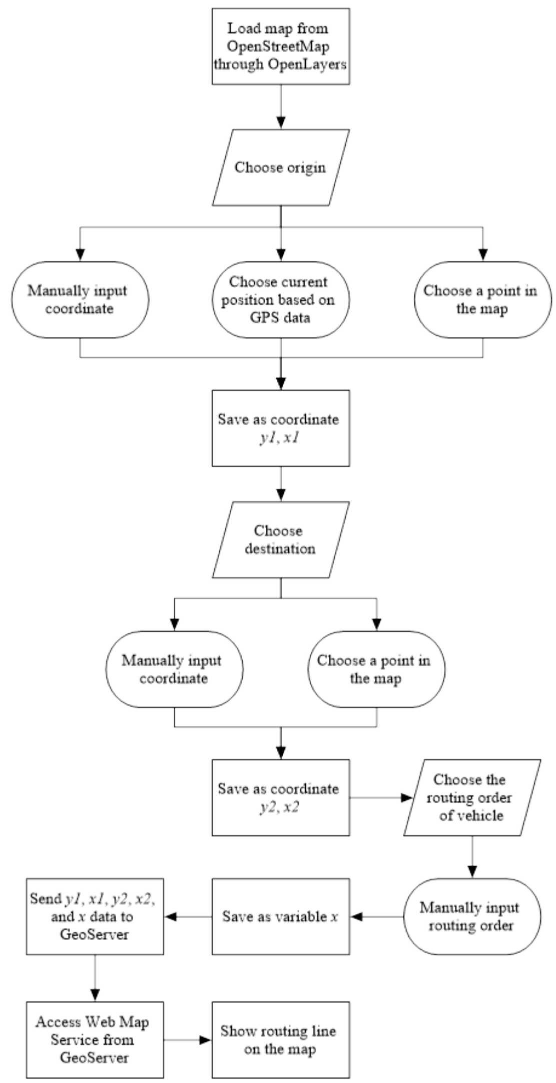

Fig. 1. Frontend Software Diagram.

Fig. 1 shows how the map data from OpenStreetMap is accessed through OpenLayers so that the data used with the web map service (WMS) protocol in GeoServer. The app needs three inputs. First, the user-selectable point of origin must be entered, either by typing in coordinates, drawing data from the smartphone GPS unit, or by selecting a point on the map. The origin latitude and longitude are stored as y1 and x1, respectively. The destination point must also be input, and its coordinates are stored as y2 and x2. If the system is to accomplish DTA, the system also needs data about how many vehicles have taken each route. This data is entered manually for the sake of simulation and is stored as variable x. This data is then passed to the GeoServer for computation. Results obtained from the GeoServer in the form of route lines are accessed from the WMS and then combined with OpenStreetMap via OpenLayers so that the route is presented to the user in an easily understandable form.

The backend software handles all computation and passes all routes back to the frontend software using the WMS protocol. Fig. 2 schematizes how the instance of GeoServer accepts the variables y1, x1, y2, x2, and x sent by the frontend and then accesses the pgRouting database. The GeoServer then runs the EBkSP algorithm and sends the variables y1, x1, y2, x2, and x to it for computation. The results from pgRouting are formatted as a list of road segments that link the origin with the destination, which are then reformatted to work with WMS.

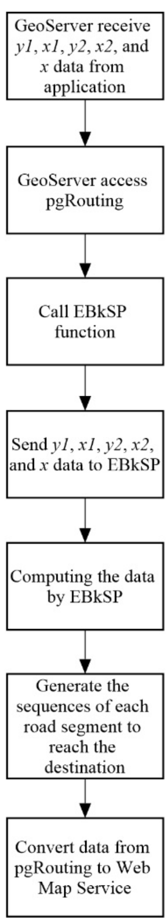

Fig. 2. Backend Software Flowchart.

IV. Test Data

A. Data Collection

We use OpenStreetMap data of Jakarta for testing, which includes vertices (intersections), lengths between vertices, road identifications, and road classes. These are included in a PostgreSQL database using the osm2pgrouting library, implementing the novel modifications to the map configuration that we described above. Fig. 3 schematizes the sequence for data collection. We chose OpenStreetMap data because it is uploaded by local contributors who know their streets well.

For testing, we entered data about the number of vehicles on each road manually. Then the results are not affected by traffic patterns like rush hour, but the tests are also not concerned with travel time, which is the only characteristic of a route that is affected by the higher density of vehicles during rush hour. The simulations also assume that all users follow the routes planned by the app.

B. Route Planning and Map

We chose a select set of origin-destination (OD) pairs for testing the route-planning algorithm, as shown in Table I. Six different OD pairs were chosen to compare routing for motorcycles with routing that includes only car-passable roads. The origin for all pairs was determined as a point on the campus of Universitas Indonesia (UI), while there were six destination points : in the “Cinere” area, in the “Lebak Bulus” area, in the “Pasar Minggu” area, in the “Ragunan” area, in the “Kebagusan” area, and in the “Jagakarsa” area. Those area are main sub-districts in the southern part of Jakarta.

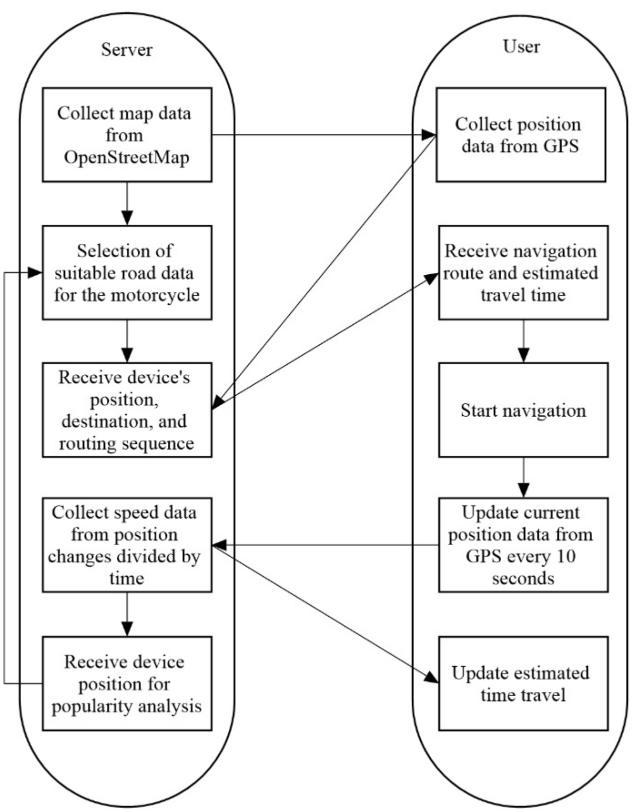

Fig. 3. Data Collection Sequences.

TABLE I. THE 6 ORIGIN-DESTINATION (OD) PAIRS FOR TESTING THE ALGORITHM

No.	OD Pairs	Coordinates	
		Origin	Destination
1	UI to Cinere	-6.36114, 106.82359	-6.33327, 106.78288
2	UI to Lebak Bulus		-6.29848, 106.77436
3	UI to Pasar Minggu		-6.28531, 106.84403
4	UI to Ragunan		-6.31071, 106.81524
5	UI to Kebagusan		-6.31132, 106.82581
6	UI to Jagakarsa		-6.32710, 106.81378

Fig. 4 shows a map of the area covered in the tests. The starting point for all the OD pairs on the campus of Universitas Indonesia (UI) is marked (coordinates -6.36114, 106.82359). Point 1 is in "Cinere" area, point 2 is in "Lebak Bulus" area, point 3 is in "Pasar Minggu" area, point 4 is in "Ragunan" area, point 5 is in "Kebagusan" area, and point 6 is in "Jagakarsa" area.

The shortest path from UI to Cinere and UI to Jagakarsa takes a narrow road (2–4 m wide); the only wider route between these two locations is much longer. For the OD pairs UI–Lebak Bulus, UI–Ragunan, and UI–Kebagusan, the shortest route uses narrow roads and a car-accessible route is available that is only slightly longer. The shortest path between UI and Pasar Minggu uses roads that are wide enough for a car to use.

Fig. 4. The Map for Testing the Algorithm: 1 (One) Starting Point on the Campus of Universitas Indonesia (UI) and 6 (Six) Destination Points.

V. RESULTS AND ANALYSIS

The performance indicators of simulated test focus on the aspect of lengths of calculated routes, distributions of vehicles on each route and computing time. Results are presented in Fig. 5, Fig. 6, and Fig. 7. Tests were also run to compare the developed EBkSP algorithm against Google Maps for motorcycles and the same application architecture with the RkSP algorithm. We also tested performance for maps configured for cars and motorcycles.

For each OD pair, three alternate routes of roughly the same distance were planned for each of the routing systems we tested. Obtaining results for each of these methods and routing configurations required performing the routing process an average of 15 times. For Google Maps, the routing process was done only once for each OD pair because the output path was always the same. The simulations assume that vehicles continue on the suggested route once they begin moving toward the destination. The backend system updates the traffic footprint data every time a vehicle makes a request for routing to a destination from the same departure point.

A. Lengths of Calculated Routes

Fig. 5 shows that the EBkSP algorithm for motorcycles returns routes of almost identical length to those planned with the RkSP algorithm for motorcycles. This result is expected because the EBkSP motorcycle configuration and RkSP motorcycle configuration use the same map configuration, and the available routes are prioritised similarly when the differences in distance between the shortest and longest routes are not very much. The routes planned by the EBkSP motorcycle configuration are shorter than those planned by the Google Maps motorcycle configuration for the UI–Cinere, UI–Ragunan, UI–Kebagusan, and UI–Jagakarsa journeys, which means that EBkSP has an advantage when narrow streets allow a shorter path to the destination point, when wide roads are not available, and when the destination point closer than 10 km from the origin.

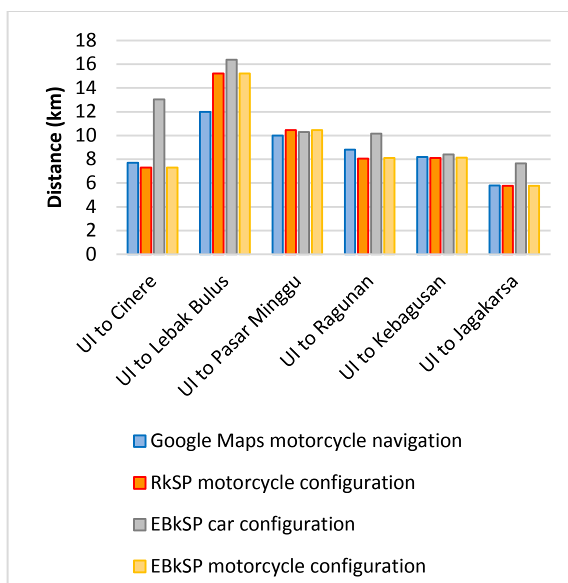

Fig. 5. Average Distances of Routes Planned by each Navigation System.

If the destination point is more than 10 km away, then the EBkSP motorcycle configuration performs no better Google Maps motorcycle configuration, as one can see in the results for UI–Lebak Bulus. Narrow roads near the campus offer a shorter path to Lebak Bulus from UI near the campus, but that path is longer than 10 km. The EBkSP motorcycle configuration plans routes that begin with a nearby wider road before taking narrow roads, while routes planned by Google Maps take the narrow roads right away for a shorter route overall. This difference in performance is explained in part by differences in some of the road data used by Google Maps and OpenStreetMap and in part by Google Maps' tendency to avoid alleyways if the difference in distance is sufficiently small.

All the configurations calculate about the same routes between UI and Pasar Minggu on a highway, and the differences in distance are explained by the algorithms' differences in calculating route distance.

These results suggest that route planning with map data configured specifically for motorcycles yields shorter routes. The EBkSP motorcycle configuration gives shorter routes than the EBkSP car configuration for all journeys except UI–Pasar Minggu, on which a wide road connects the origin and destination directly.

B. Distributions of Vehicles on each Route

Standard deviations can be used to express how evenly the route-planning algorithms distribute vehicles among the possible routes between two points. If the standard deviation is lower, the vehicles are more evenly distributed, so congestion will be less likely to arise. The average standard deviation of the number of vehicles on each route from the mean is plotted for each routing algorithm in Fig. 6. The RkSP motorcycle configuration routes have standard deviations of 1.73 vehicles per route on OD UI–Cinere, 2.65 vehicles per route on OD UI–Lebak Bulus, 2.65 vehicles per route on OD UI–Pasar Minggu, 3.61 vehicles per route on OD UI–Ragunan, 2.65 vehicles per route on OD UI–Kebagusan, and 4.36 vehicles per route on OD UI–Jagakarsa. The RkSP algorithm assigns routes of the same length to users randomly, so vehicles taking those routes can pile up on one route and increase the potential for congestion. The plot in Fig. 6 includes no bars for the EBkSP routes because the standard deviation of vehicles on each route was zero; i.e., the EBkSP algorithm distributes vehicles evenly among routes.

These results show that the EBkSP algorithm is effective for DTA using only the history of routes suggested by the navigation system, under the assumptions we have applied to the above simulations. The algorithm calculates the popularity of each route from the number of vehicles that have taken that route to and preferences unpopular routes, updating this entropy calculation with each route it suggests. By definition, this algorithm will spread users of a navigation system evenly among alternate routes to get around traffic congestion. This even distribution of vehicles among routes suggests that an open-source navigation app using EBkSP can effectively avoid the accumulation of vehicles on one route, so that such an app would be unlikely to exacerbate congestion.

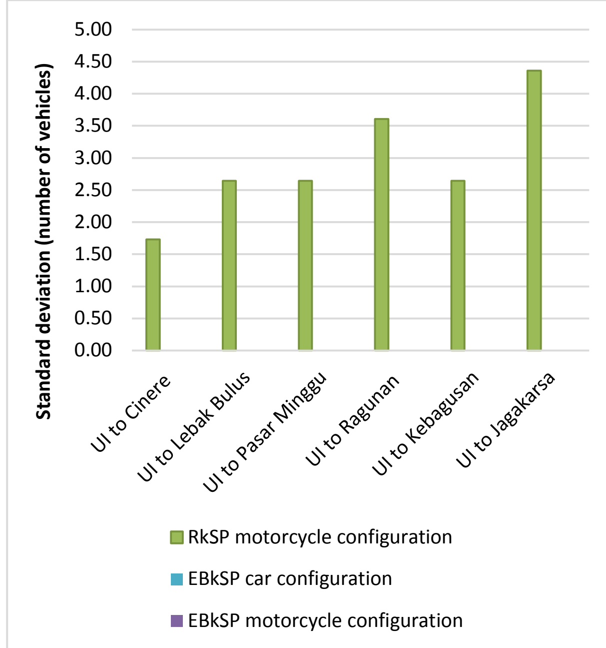

Fig. 6. Standard Deviations for Vehicle Distribution on each Route. Data for EBkSP Algorithms is not Visible because all Values are Zero.

C. ComputingTime

Since the EBkSP algorithm is more complicated than the RkSP algorithm, it will take longer to compute, so we need to check that the computing time is not so long as to make the EBkSP algorithm impractical. The EBkSP algorithm is applied to the PostgreSQL database of map and traffic data in three stages: route sorting based on length, calculating the popularity of each route, and choosing the best route while minimising length and popularity. This computation takes more time than RkSP, which simply assigns shortest routes randomly. Fig. 7 shows that the computation time for EBkSP considering motorcycle-accessible routes is the longest, as expected, but the EBkSP algorithm still returns routes faster than the Google Maps API. The EBkSP car configuration happens to compute faster than the RkSP motorcycle configuration for the origination-destination pairs considered in the present tests.

The relatively long computation time of the Google Maps motorcycle configuration is explained by the detailed graphics of the route lines created and the calculation of the average speed of each different road segment, which is not considered by the other algorithms we tested. Motorcycle routes take longer to compute in all cases because more roads are considered as possible; the algorithm considers only wider roads when calculating routes for cars.

D. Discussion

This paper propose the navigation app for motorcycle using EBkSP algorithm. Performance of the app is measured using three parameters: length route, vehicle distribution, and computing time. Testing is conducted by comparing measurement result with the data from Google Maps. The app is superior for determining shortest path when taking into account the narrow streets. Moreover, taking popularity parameter of the routes can avoid the users pass the same route and distribute into different routes. The last parameter is computing time. Taking into account the narrow streets means that the app requires more time for making decision. However, the proposed app still outperforms the Google Maps in term of computing time.

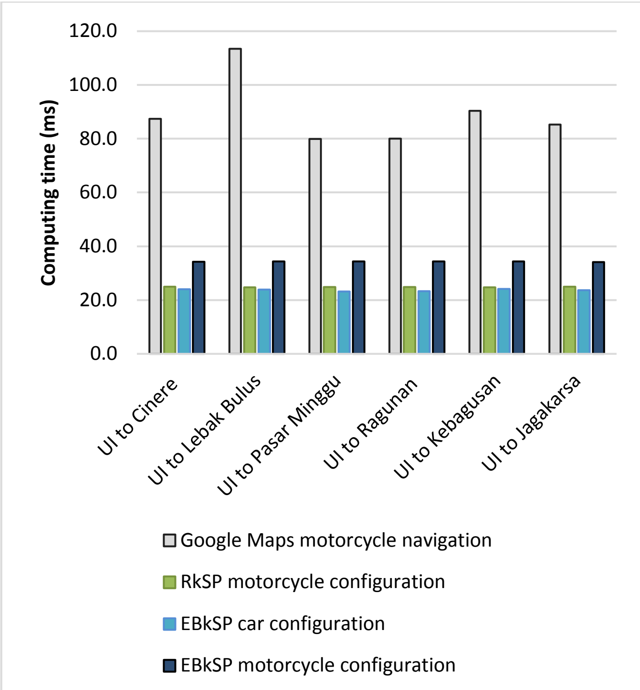

Fig. 7. Average Computing Time for Planning Routes between each Origin-Destination Pair.

VI. Conclusion

The simulation tests suggest that the proposed routing algorithm is advantageous when the destination is within 10 km and can be reached via a shorter route using narrow streets. Motorcyclists can use the system to reach their destinations up to 8% faster than they can with Google Maps for motorcycle riders and up to 44% faster than the EBkSP algorithm for cars, if they are travelling between areas of Jakarta linked by narrow streets. EBkSP accomplishes Dynamic Traffic Assignment (DTA) in that it prevents congestion by directing vehicles to less-popular routes. Computing time is affected more by the configuration of the routing algorithm for car or motorcycles than the particular algorithm used. These results show that an open-source route-planning algorithm for motorcyclist use can offer improved performance over algorithms that consider only routes that are navigable by cars. The EBkSP algorithm shows clear promise for use in a navigation system that achieves DTA without the need for ubiquitous traffic-data infrastructure. In the future research, taking into account as many as possible of traffic attributes such as number of traffic light and cross section, can improve performance of routing.

Acknowledgment

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Identity Attributes Metric Modelling based on Mathematical Distance Metrics Models

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Abstract—**Internet has brought a lot of security challenges on the interaction, activities, and transactions that occur online. These include pervasion of privacy of individuals, organizations, and other online actors. Relationships in real life get affected by online mischievous actors with intent to misrepresent or ruin the characters of innocent people, leading to damaged relationships. Proliferation of cybercrime has threatened the value and benefits of internet. Identity theft by fraudsters with intent to steal assets in real space or online has escalated. This study has developed a metrics model based on distance metrics in order to quantify the credential identity attributes used in online services and activities. This is to help address the digital identity challenges, bring confidence to online activities and ownership of assets. The application forms and identity tokens used in the various sectors to identify online users were used as the sources of the identity attributes in this paper. The corpus toolkits were used to mine and extract the identity attributes from the various forms of identity tokens. Term weighting schemes were used to compute the term weight of the identity attributes. Other methods used included Shannon Entropy and the Term Frequency-Inverse Document Frequency scheme (TF*IDF). Standardization of data using data normalization method has been applied. The results show that using the Cosine Similarity Measure, we can identify the identity attributes in any given identity token used to identify individuals and entities. This will help to attach the legitimate ownership to the digital identity attributes. The developed model can be used to uniquely identify an online identity claimant and help address the security challenge in identity management systems. The proposed model can also identify the key identity attributes that could be used to identify an entity in real or cyber spaces.**

Keywords—Mathematical modeling; Cosine Similarity Measure; text frequency; inverse document frequency; cyber space; term weight; internet; digital identity; trust model; normalization; text mining

I. Introduction

Challenges of identifying internet users associated with valuables that are online have become a serious concern to internet users. The adverse challenges on information security regarding identification of real identity ownership on internet and to services and online activities is of great concern. This research has developed a metrics model based on distance metrics in order to quantify the credential identity attributes used in online services and activities. The model will help in improving cyber security in digital identity management.

This study has reviewed literature that is relevant to the work so as to establish what passed efforts in this area have covered. Areas that have been explored include effects of internet to society and studies that help to understand what identity is from various disciplines. Various forms of identities have been considered which form partial identities, these would have an impact on identity of a person or entity. Consideration of what identity would imply on online services and activities has been looked at so as to have a relevant context in this study. Digital identity is an aspect that is dependent on trust; it is imperative to reflect on trust framework so as to bring to the fore on how the digital identity and trust are inter related. A large part of online activities includes communication of information; we therefore, had to reflect on communication trust model which would be applicable to our study and see the value that it would add to our study. We have reflected on Shannon’s Communication trust framework from Shannon’s Information theory to guide us in considering digital identity with respect to trust in online activities. Since our work is premised on mathematical modeling, it was imperative that we draw our attention to mathematical modeling and how it could influence our work. This research includes text mining from different documents, the mining would give outcomes that would include errors on data from different backgrounds of the different documents, whose sources are varied. To remove errors which at time would be due to measurement units, noise, and estimations, standardizing of data would be important before we use it in our metrics.

Mathematical modeling has been used in science in finding solutions in real life problems, this study takes interest in mathematical modeling. Using a mathematical model, a solution is being proposed to attend to the challenges that have been encountered in cyberspace concerning digital identity security. The study will use the proposed model on mined data to quantify the identity attributes. We will use the model to verify identification of the owner of digital identity; we will further test the model and establish which identity attributes are key in a given corpus for the identification of an identity claimant.

Literature that was reviewed showed that vector space model uses a storage matrix where columns represent the documents in a collection and rows represent terms in a document. Term frequencies of a given document would help us establish important identity attributes which would identity an entity. Literature indicated that there is a variety of schemes on term weights (attribute importance) which would help us establish whish terms are important in a given token of identity. Some of the schemes (or information retrieval methods) include Shannon's entropy and Term Frequencies - Inverse Document Frequency (TF-IDF). Our interest is to develop a digital identity model that would supply trusted digital identities. The other literature that was reviewed was that on multifactor authentication systems on identity attributes metrics models. This was to help us consider efforts that have been used in the past on augmented efforts. Literature on International Standards regarding identity attributes and identity tokens to appreciate the value this would have on our work was considered. This was to establish the international standards that affect identity attributes and identity tokens which are subject of our study.

Identity attributes were mined from identity documents and application forms for identity enrolment. Such documents in PDF format were extracted from internet using TalkHelper PDF Converter. Text was then mined from these documents using AntConc 3.5.8, a corpus analysis toolkit for data mining. To remove error, data was normalized for standardization of data.

The proposed model was used for identity attribute quantification and verification. The proposed model was also used to determine term importance in the corpus. Distance metrics has been the basis of our model to quantify the identity attributes. The model would identify attributes that are very key as identifiers of an entity, in other words, these are attributes that can closely identify an entity in online activities. Results of our study have been given and conclusion of the study has been drawn.

II. Literature Review

A. Adverse Effects of Internet

The rapid development of information and communication networks by governments, colleges, enterprises and individuals means that they are employing more and more information systems without clear distinctions of the persons and devices behind their use [1]. It is obvious that the need for identity that would provide complete privacy is vital [1]. It has been established that cybercrime has become one of the fastest growing crimes in the world [2]. Study has showed that computer networks are subject to attacks from malicious sources, with the advent and increasing use of internet attacks are most commonly increasing [3]. In 2007 it was reported that, "in Australia alone the proceeds of identity theft, [was] still one of the largest sources of fraud, [and was] estimated to be nearly $6 billion a year [4]". Identity theft is one of the fastest growing crimes in the world. Security includes protecting individuals, organizations, devices and infrastructure from identity theft, unauthorized data sharing and human rights violations [5]". When devices are lost or stolen, all of the data stored on or accessible from the mobile device may be compromised if access to the device or the data is not effectively controlled [6].

B. Partial Identity

To appreciate identity, we need to consider that a wholesome identity is formed by partial identities. A person may have different identities according to the context in which the identity is applied. For instance, a researcher may be a father, magazine columnist, human right activist, sportsman, politician, philanthropist, friend, and lecturer. He is identified differently, and attributes that make him identified accurately may differ from one context to the other. Fig. 1, illustrates partial identities. A comprehensive identity could be assumed by identifying key characteristics of an individual which we would attribute to be identity attributes.

Identity encompasses all the essential characteristics that make each human unique [3]. An identity of father of this individual may have characteristics of: father of three, kind, loving, hardworking, protective, supportive, merciful, jovial, progressive, etc. The identity of a person comprises a large number of personal properties [3], as indicated above. These properties help to uniquely identify an individual.

C. Digital Identity

It is indicated in [7] that "a digital identity is a virtual representation of a real identity that can be used in electronic interactions with other machines or people". An identity consists of traits, attributes, and preferences upon which one may receive personalized services". E-services require an effective way to manage digital identity information of the users [7].

Windley defines a digital identity as the "data that uniquely describes a subject or an entity and the ones about the subject's relationships to other entities [8]". Further, Windley states that a digital identity is "the persona that an individual presents across all the digital spaces [8]". In [9], we define digital identity as the "electronic representation of personal information of an individual or organization (name, address, phone numbers, demographics, etc.)".

We discover that "in the digital world a person's identity is typically referred to as their digital identity [9]". It is argued in [10] that "identity encompasses all the essential characteristics that make each human unique". Satchell et al. indicated that "identifiers of a respective individual or entity would identify the entity online, from any context of the identity. An identifier uniquely identifies an entity (a person, a computer, an organisation, etc.) within a specific scope [11]". This underscores that digital identification is key in online activities of an entity on internet or computer network.

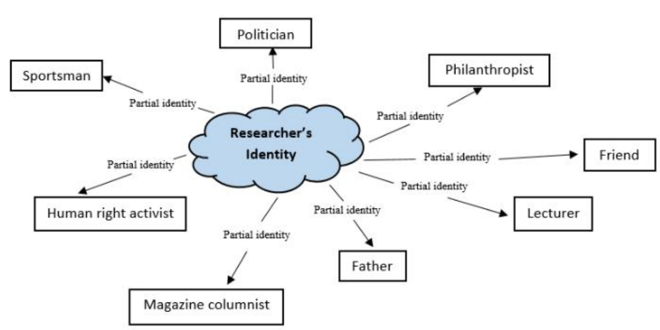

Fig. 1. Illustration of Partial Identity.

ISO/IEC 29003:2013 [12] gives a list of recognized tokens of identification as international standards on identity tokens. The token of identification is meant to fully distinguish the rightful owner of the token. The digital identity has attributes that help to establish an identity of an entity on online activities and services. In [12], we get a list of internationally accepted attributes that can identify an individual online. Identity attributes of a person or entity form a representation of an individual or entity through a given identity token. The relationships between an entity, identity token, digital identity, and identity attributes are presented in Fig. 2.

Due to the unrestrictive nature of the Internet, without proper identification and authentication, users are becoming more vulnerable to identity fraud and theft. Online identity theft, fraud, and privacy concerns have become a huge issue now; identity theft is big business [13]".

D. Communication Trust Model

Trust is an important ingredient during online communication between entities. However, such communication may not be immune to bad elements scavenging on the internet. It was observed that "[a hacker] could exploit a user's indoor location data to infer a variety of personal information, such as work role, smoker or not, coffee drinker or not, and even age [14]". It is imperative that such risks are eliminated by exploring solutions to such problems. Trust [which is] defined as "a psychological state comprising the intention to accept vulnerability based upon positive expectations of the intentions or behavior of another [15]" is a basic constituent of social life [16],[17]. A trust framework model based on "the communication model by Shannon and Weaver [18] was adopted, incorporating the sending and receiving process of an individual according to the three tier approach of data, information, and knowledge. The Shannon and Weaver [18] model is one way directed and stems from the domain of information theory. In this model "a trustor places trust in the trustee [18]". Fig. 3 illustrates the Communication Trust Framework guiding the Shannon and Weaver model. "Communication consists of four major components the sender, the receiver, the message, and the environment. The communication process can generally be distinguished in the three phases sending, transmitting, and receiving. The phases of sending and receiving are concerned with the process of the message formation and comprehension by the sender and the receiver respectively [18]". The study by Memon and Arain shows that "communication requires adequate privacy level [19]" to improve security of information and online services; these could be assets that could be affected in online communication of entities. It was observed that "preserving privacy [in communication] is an important challenge [20]". This is necessary so as to ensure that only those that are entitled to private information or private online services have access to such. Sensitive information and services should be limited to only those that are privy to such assets. However, there has to be "a balance [between] service quality and privacy protection [20]". This would help to maximize the benefits of services and securing the interests of the legitimate digital identity owners to improve service quality amidst security of service.

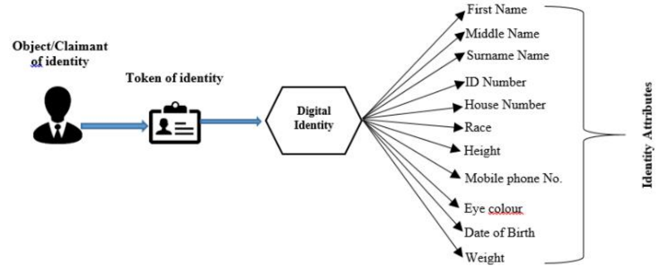

Fig. 2. Representation of Digital Identity by Identity Attributes.

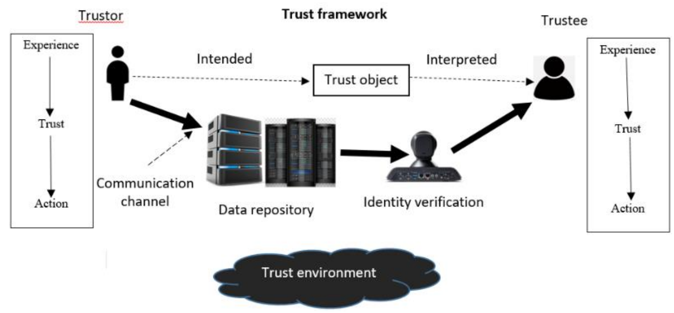

Fig. 3. Communication Trust Framework.

E. Mathematical Modeling

Haines and Crouch (2007) characterize "mathematical modeling as a cyclical process in which real-life problems are translated into mathematical language, solved within a symbolic system, and the solutions tested back within the real-life system [21]". This demonstrates how mathematical modelling can present a mathematical model that would help in solving a real life situation using mathematics. It is the interest of this research to establish a model that would help in presenting a solution to the problem of this research using a mathematical model. "Mathematical models comprise a range of representations, operations, and relations, rather than just one, to help make sense of real-life situations [22]".

F. Data Standardization

"We often want to compare scores or sets of scores obtained on different scales [23]". Standardizing data that comes from different sources would help us to "eliminate the unit of measurement by transforming the data into new scores with a mean of 0 and a standard deviation of 1. Considering that this research has interest to compare with the performance of other metrics, it is prudent that we have a common ground of comparing the performance of the metrics. We transform data "to improve our ability to discover knowledge [24]"; this transformation "includes normalising data [24]." Olson and Delen in [25] indicate that "the main advantage is to avoid attributes in greater numeric ranges dominate those in smaller numeric ranges. Another advantage is to avoid numerical difficulties during the calculation." It was noted that "normalization may improve the accuracy and efficiency of mining algorithms involving distance measurements [26]". We discover that "a direct application of geometric measures (distances) to attributes with large ranges will implicitly assign bigger contributions to the metrics than the application to attributes with small ranges. The attributes should be dimensionless because the numerical values of the ranges of dimensional attributes depend on the units of measurements and, therefore, the choice of the units of measurements may greatly affect the results of clustering. One should not use distance measures without normalization of data [27]".

III. Related Works

Campbell et al. state that "in the simplest case, the components of [the sparse] vectors are the raw frequency counts of each term in each document [28]". They also observed that "search engines of the World Wide Web (www) are based on certain information retrieval models like Boolean model, Probabilistic model, and Vector space model [28]". Our interest is in the vector space model; Campbell et al. indicate that "the main purpose of [information retrieval models] is to retrieve relevant documents specific to a search [28]". It was observed that "[vector space model] uses a storage matrix where columns represent the documents in a collection and whose rows represent the term frequencies among the documents [28]". They also stated that "For ad-hoc querying, dynamic queries are compared against a static document database in order to find documents closest to the query [28]". Simplistically speaking, a search engine has "static database of documents, a query processor, to convert incoming (dynamic) queries into a format compatible with the representation model, and a relevant measure to compare converted queries against documents [28]". The researchers indicate that "when conducting a query, one method is to search through the storage matrix and match the query terms with row terms producing the document closest to the query [28]".

Researchers have established that "Shannon's entropy method is one of the various methods for finding weights [29]". It has been observed that "multiple attribute decision making (MADM) refers to making preference decisions (e.g., evaluation, prioritization, and selection) over the available alternatives that are characterized by multiple, usually conflicting, attributes [29]". It was observed that "since each criterion has a different meaning, it cannot be assumed that they all have equal weights, and as a result, finding the appropriate weight for each criterion [29]". They discovered that "in MADM the greater the value of the entropy corresponding to a special attribute, which imply the smaller attribute's weight, the less the discriminate power of that attribute in decision making process [29]".

It is indicated in [29] that "the raw data are normalized to eliminate anomalies with different measurement units and scales. This process transforms different scales and units among various criteria into common measurable units to allow for comparisons of different criteria". It was showed in [30] that "the entropic-weight method, from Shannon's entropy theory, was applied for the purpose of obtaining a classification". Vajapeyam, summarizes "Shannon's entropy [as] a direct measure of the number of bits needed to store the information in a variable, as opposed to its raw data [31]". He adds that "entropy is a direct measure of the 'amount of information' in a variable [31]".

Inambao et al. came up with a digital identity model that would "supply trusted digital identities [32]"; the model would "identify and extract various forms of identity attributes from various forms (identity tokens) [32]". The model was established on Euclidean Distance metric based on Euclidean geometry. This model identified attributes that were very key as identifiers of an entity, in other words, these are attributes that can closely identify an entity. This model helps in "quantifying, implementing, and validating of the attributes from application forms (or identity tokens) [32]".

Chinyemba and Phiri [33] showed "how to secure biometric data whilst at rest and or in motion so as to deter attackers in public organizations". Biometric identification contributes immensely to a person's identification and can therefore, contribute to the collection of digital identity attributes for individual identification. Ibou et al. indicated that "attribute-based digital identity modelling [needed] to take into account privacy issues [34]" and "proposed [a] model [that] takes into consideration three fundamental aspects, namely security, privacy and identity theft [34].

The work of Phiri et al. introduced a "multifactor authentication system based on two identity attributes metrics models [35]". This broadens the scope of digital identification in an Identity Management system; we could have different modes of identification to make the digital identification robust and effective. Strengthening of the security of digital identity would include the developing of multi-modal authentication. This would include a combination of different authentication methods. For instance, like in the case of "when using an ATM bank card, in addition to the PIN number the user may be requested to submit a biometric feature such as a fingerprint in order to withdraw a certain amount of money above a given limit. A combination of biometrics, token based credentials and pseudo metrics will most likely form a very effective defense against imposters [35]". The researchers where hoping that "an additional fourth category of inputs would take into account identity attributes such as the name, date of birth, address and other acquired identity attributes for consideration [35]". Our research efforts are building on these past research work.

The work of Phiri et al. introduced a "multifactor authentication system based on two identity attributes metrics models [36]". They argued that this would "reduce the cases of cybercrime since it becomes difficult to forge all the proposed four authentication factors that include biometrics [36]". They went on to demonstrate "the performance of the three fuser block technologies namely Artificial Neural Networks (ANN), Fuzzy Inference System (FIS) and Adaptive Neuro-Fuzzy Inference System (ANFIS) using the term weight and entropy identity attributes metrics.

The current research was given birth by this work of Phiri et al. as indicated in the close of their work indicating that they considered the "future works [would] look at other combinations of the authentication factors and metrics modelling methodologies [36]".

IV. Research Method

Consulting Creswell [37] indicates that this study is quantitative in nature and therefore, a survey to inquire into perceptions of observers was planned to use a questionnaire that would attend to these perceptions. As this study is quantitative in nature, extensive literature in quantitative studies was reviewed. Previous works that have applied the areas that have a bearing on this research with quantitative techniques applied were reviewed. Quantitative data was analyzed with the help of spread-sheets (e.g. Microsoft Excel). The techniques that have been used include data mining techniques and statistical analysis. PDF application forms for identity token requesting for identity attributes of individuals, within the research sample, were extracted from internet. The identity attributes were drawn from a list of internationally identified identity attributes by the International Standard Organization (ISO).

Documents in PDF format from the corpus of the Government of the Republic of Zambia (the researcher's residence) documents were searched and harvested from the internet. To test the proposed model, we got a set of application forms for identity token at random from our selected area. We picked ten (10) documents from the pdf documents out of 32 documents that were extracted from internet. Our model is focused on identifying the set of attributes that would identify a claimant of a digital identity that sufficiently matches the entity to be identified. Matching of a claimant could be done on one claimant or multiple claimants. In simple terms from our documents, if one document represents a token that owns the digital identity which is being claimed by the claimant, we can compare the attributes of digital identity of this entity to those of the claimant. For the purposes of this research, the ten documents will suffice, of which one would be the object and nine others will be the claimants of the digital identity. All the ten documents were tested on the metrics in the proposed mathematical model.

As indicated, ten (10) documents were picked from the Government of Zambia sets of documents. These documents are listed in Table I.

A. *Identity Attribute Text Mining*

Literature for International Standard Organization was consulted to identify attributes that are recognized as standard in the enrolment of diverse online services. Therefore, identified attributes by International world standards, ISO/IEC JTC 1/SC 27, were considered and used in this research. These standards have identified a list of attributes that could be collected from individuals during the time of enrolment for digital services of individuals; "Validation can occur during Identity Proofing, Identity Information Verification and Verification" [38] regarding entities from identity tokens. A list of attributes from ISO/IEC JTC 1/SC 27 indicates elements that would form identifiers to identify an individual, these are shown in Table II.

Tokens of identity are equally identified by this ISO standard. The identity documents and service enrolment application forms are documents that fell in the category of the international standards of ISO/IEC 29003:2013 [38]; These documents, according to the research samples, were searched from the internet and obtained in PDF format. TalkHelper PDF Converter version 2.2.9.0 tool was used to convert documents into PDF, for documents that were in other formats other than PDF. Documents which were already in PDF needed no format conversion. Fig. 5 shows TalkHelper PDF Converter that we used in this study.

Documents in PDF format were then converted into text files (using TalkHelper PDF Converter version 2.2.9.0) in readiness for text mining. AntConc 3.5.8, a corpus analysis toolkit was used for text mining. This tool was used to get the text frequency of the corpus files from different industries and regions, as discussed above, that were imported into the tool from respective folders. Fig. 4 shows the tool that was used for text mining.

Each identity attribute had its term frequency recorded as indicated, from corpus analysis toolkit. Text mining was done on these documents using the same techniques as discussed above, based on the nineteen (19) existing attributes that we have been using. Table III shows the term frequencies (*Tf*) of each of the respective attributes after text mining.

TABLE I. SAMPLED DOCUMENTS FOR TERM WEIGHTING

Code	**Document name**	**Code**	**Document name**
D1	Airspace application form	D6	Residential Land acquisition application form
D2	Residence Permit application form	D7	Aquaculture Fund application form
D3	Visiting Visa application form	D8	Borehole Form application form
D4	Consent Form application form	D9	Health Professional Council membership application form
D5	Farm small holding application form	D10	Immovable Property application form

TABLE II. A LIST OF STANDARD ATTRIBUTES BASED ON ISO

Attributes (ISO/IEC JTC 1/SC 27)			
First name	Race	ID Number	Work telephone number
Middle name	Gender	Issuing authority	Work email address
Last name	Home address	Expiry date	Bank account details
Date of Birth	Home Unique Property Reference Number (House Number)	Home email address	Height
Place of Birth	Home telephone number	Work address	

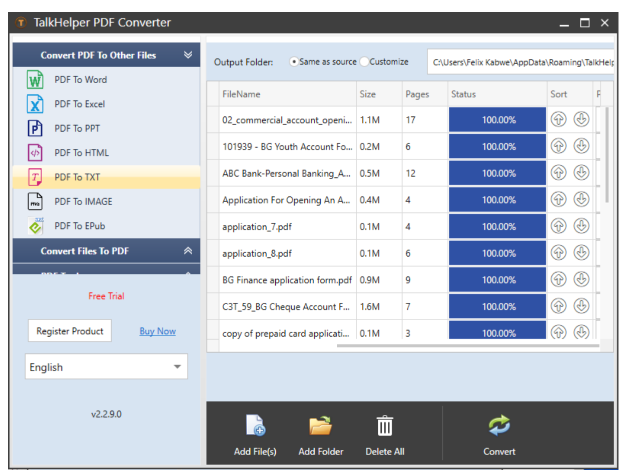

Fig. 4. TalkHelper PDF Converter Version 2.2.9.0.

TABLE III. TERM FREQUENCIES OF TEN DOCUMENTS FOR COMPUTING TF*IDF WEIGHTING (ZAMBIAN FIGURES)

ATTRIBUTE	Term (Tf_i)									
	D1: Tf_1	D2: Tf_2	D3: Tf_3	D4: Tf_4	D5: Tf_5	D6: Tf_6	D7: Tf_7	D8: Tf_8	D9: Tf_9	D10: Tf_{10}
First name	5	5	4	2	4	4	2	3	1	2
Middle name	5	5	4	2	4	4	2	3	1	2
Last name	5	5	4	2	4	4	2	3	1	2
Date of Birth	0	5	2	0	0	0	0	0	1	0
Place of Birth	0	3	3	0	0	0	0	0	0	0
Race	0	0	0	0	0	0	0	0	0	0
Gender	0	3	3	0	2	2	0	0	1	0
Home address	1	1	2	3	4	1	3	0	1	3
House Number	1	0	0	0	0	0	0	0	0	1
Home telephone number	1	0	0	1	1	1	1	0	0	0
ID Number	1	1	1	0	1	1	1	0	1	0
issuing authority	1	0	0	1	1	1	0	1	1	1
Expiry date	0	1	1	0	0	0	0	0	0	0
Home email address	0	0	0	1	1	1	1	0	1	0
Work address	1	1	0	2	4	1	0	0	1	3
Work telephone number	1	0	0	1	1	1	1	0	1	0
Work email address	0	0	0	1	1	1	1	0	1	0
Bank account details	0	0	0	0	0	0	0	0	1	0
Height	0	0	0	0	0	0	0	0	0	0
Sum	**22**	**30**	**24**	**16**	**28**	**22**	**14**	**10**	**13**	**14**

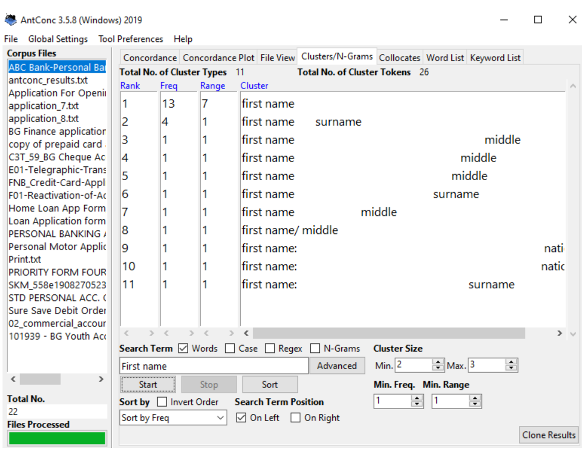

Fig. 5. AntConc 3.5.8, a Corpus Analysis Toolkit for Data Mining.

"As the time passes, a lot of information and new challenges related to information acquisition and data mining are emerging very rapidly [39]". Efforts of curbing online risks ought to match the rapid growth of technology and online services.

V. PROPOSED MODEL

The proposed model Identity Attribute Metric Model based on the Distance Metrics in this research is the Cosine Similarity measure.

A. Model Quantification

A cluster is a collection of data objects that are similar to objects within the same cluster and dissimilar to those in other clusters. Similarity between two objects is calculated using a distance measure [40]. Charulatha et.al indicate that "Clustering is the grouping of similar instances/objects some sort of measure that can determine whether two objects are similar [26]". As pointed out by Backer and Jain, "in cluster analysis a group of objects is split up into a number of more or less homogeneous subgroups on the basis of an often subjectively chosen measure of similarity (i.e., chosen subjectively based on its ability to create 'interesting' clusters) [34]". "From the scientific and mathematical point of view distance is defined as a quantitative degree of how far apart two objects are [41]."

Researchers note that "it is natural to ask what kind of standards we should use to determine the closeness, or how to measure the distance (dissimilarity) or similarity between a pair of objects, an object and a cluster, or a pair of clusters [34]". "In order for the distance metrics to make sense, good data transformation or normalization is required. In data normalization methods, the objective is usually to ensure that the computed distance metric or similarity measure will reflect the inherent distance or similarity of the data [42]".

When documents are represented as term vectors, the similarity of two documents corresponds to the correlation between the vectors. This is quantified as the cosine of the angle between vectors, that is, the so-called cosine similarity. Cosine similarity is one of the most popular similarity measure applied to text documents, such as in numerous information retrieval applications and clustering too [42]. An important property of the cosine similarity is its independence of document length. For example, combining two identical copies of a document d1 to get a new pseudo document d2, the cosine similarity between d1 and d2 is 1, which means that these two documents are regarded to be identical. Given another document d3, d1 and d2 will have the same similarity value to d3 [42] as shown in equation (1).

$$\text{Sim}\left(Tf_{d_1}, Tf_{d_3}\right) = \text{Sim}\left(Tf_{d_2}, Tf_{d_3}\right) \quad (1)$$

Documents with the same composition but different totals will be treated identically. When the term vectors are normalized to a unit length such as 1, and in this case the representation of d1 and d2 is the same [42].

Cosine similarity measure has a high positive correlation than the Euclidean Distance [43]. The cosine of 0^0 is 1 and it is <1 for any other angle. It is thus a judgment of orientation and not magnitude: two vectors with the same orientation have a cosine similarity of 1, two vectors at 90^0 have a similarity of 0 and two vectors diametrically opposed have a similarity of -1, independent of their magnitude. Cosine similarity is particularly used in positive space where the outcome is nearly bounded in [0,1]. Cosine similarity is particularly used in positive space where the outcome is nearly bounded in [0,1] [43]. Cosine similarity gives a useful measure of how similar two documents are likely to be in terms of their subject matter [43]. This distance metric will give us a number from the closed interval [0, 1], 0 denoting that the two vectors are overlapping and 1 denoting that there is an angle of 90 ° which is the highest difference between the vectors [44].

Cosine Similarity is a measure of similarity between two vectors of an inner product space that measures the cosine of an angle between them [44]. It can be derived using the Euclidean dot product. Given two non-zero vectors, "x" and "y", the dot product of the two vectors would be represented by

$$\boldsymbol{x.y} = \|\boldsymbol{x}\|\|\boldsymbol{y}\| \, Cos\,\theta \quad (2)$$

This will translate to

$$Cos\,\theta = \frac{\boldsymbol{x.y}}{\|\boldsymbol{x}\|\|\boldsymbol{y}\|} \quad (3)$$

This also agrees with trigonometry and complex numbers; given two vectors, x and y in a vector space, the Cosine of the angle (θ) between these two vectors would be represented by the equation above.

Given two vectors X and Y, the Cosine Similarity, Cos (θ) is expressed as a dot product and magnitude as

$$\text{Similarity} = S(X,Y) = Cos\,(\theta) = Cos\,(X,Y)$$

$$= \frac{X.Y}{\|X\|\|Y\|} = \frac{\sum_{i=1}^{n} X_i Y_i}{\sqrt{\sum_{i=1}^{n} X_i^2}\sqrt{\sum_{i=1}^{n} Y_i^2}} \quad (4)$$

These two vectors could be that "X" is a set of attributes that of an applicant who claims ownership of the identity attributes while "Y" could be verifier identity attributes. The Cosine function in equation (3) can be represented as a Similarity distance measure in equation (4) as is also indicated in [45].

B. *Identity Verification*

The choice of this model was based on two considerations that could be applied in this study:

1) For verification of ownership

a) When we are specifically interested in attending to one applicant for verification of ownership claim of a particular digital identity with known identity attributes.

b) When multiple applicants make claims of ownership claims of a particular digital identity with known identity attributes and we need to verify.

2) The principle of orientation of two similar vectors in a metric space that is inherent with the cosine Similarity distance.

Cosine Similarity measure is used in data mining as a technique for documents that are similar based on the text that these documents contain. For instance, this metric is used in considering those who share same tags on a blog, persons who viewed same documents, customers who bought similar items online.

Verifying online identity for claimants could help establish who the legitimate owner would be from a multiple of identity claimants. We could use the metrics and mathematical computations to achieve this. Therefore, this model can be used in the verification process of an applicant or applicants in the Digital Identity Management System.

C. *Testing the Model*

For us to identify the hierarchy of importance of attributes in the corpus, we need to consider the term weight of each attribute within the corpus of the ten (10) documents. We have represented the ten (10) documents in our functions as d_1, d_2, d_3,…d_{10}. The general expression of d_i, represents the same ten documents ranging from d1 to d_{10}.

Chen and Chang indicate that "TF and TF-IDF are widely applied to count the weight of a term" [43]. They further add that "TF represents the number of times a term occurs in a document, and TF-IDF is the combining of TF and IDF weights. IDF indicates the general importance of a term in overall documents" [43].

Researchers indicate that Term frequency (*Tf*) factor is represented by the "logarithm of the term frequency to scale the effect of unfavorably high term frequency [44]". This is expressed as.

$$\text{TF} = 1 + \log tf \quad (5)$$

D. *Indeterminate Considerations*

It is important to recognize that the function $\mathbf{log}\,\boldsymbol{tf}$ runs into indeterminate when $\boldsymbol{tf}$ becomes zero (0) since

$\log 0 = \infty$ and

$1 + \infty$ are indeterminate

We therefore, evaluate this part of the function; we have a logarithmic property that for any n = 1, 2, 3, … we have

$$\frac{x-1}{x} \leq f_n(x) \leq x-1 \quad (6)$$

Therefore,

$$\frac{x-1}{x} \leq \log x \leq x-1 \quad (7)$$

It follows that the upper bound of log x is x – 1

Therefore, replacing ***tf*** in the function $TF = 1 + \log tf$ we have

$$TF = 1 + (x-1) \quad (8)$$

For x = 0, we have

$$TF = 1 + (0-1) = 0 \quad (9)$$

The Inverse Document Frequency component (IDF) of the function is expressed when we "multiply original *tf* factor by an inverse collection frequency factor (N is the total number of documents in a collection, and n_i is the number of documents to which a term is assigned) [43]".

It was indicated in [46] IDF can be calculated by

$$\text{idf} = \frac{\textit{The number of total docments}}{\textit{The number of documents include term}} \quad (10)$$

This is represented by the expression:

$$\text{IDF} = \log \frac{N}{n_i} \quad (11)$$

This function will be indeterminate when $n_i = 0$. We observe that

$$\log \frac{N}{n_i} = \log N - \log n_i \quad (12)$$

In our corpus, N = 10. We could have situations when n_i = 0; at that point then our function would become indeterminate.

That is,

$$\text{IDF} = \log 10 - \log 0 = \log 10 \quad (13)$$

From our established statement above, in (7), it therefore follows that

$$\text{IDF} = \log 10 - (x-1) \quad (14)$$

When x = 0, then we have

$$\text{IDF} = \log 10 - (0-1) = \log 10 + 1 \quad (15)$$

Table IV represents the term frequencies (*TF*) of the corpus. The functions in Table IV, Table V, and Table VI for the term frequencies Tf_i and idf_i, have their indeterminate logarithmic functions resolved and therefore, present the outcomes of the functions.

In 1993 Buckley stated that "over the past 25 years, one class of term weights has proven itself to be useful over a wide variety of collections. This is the class of *tf*idf* (term frequency times inverse document frequency) weights [47]". "TF-IDF is also one of the most popular term-weighting schemes for user modeling and recommender systems [48]".

Considering the TD-IDF term weight scheme, from our findings above, we would have the weighting computational outcomes to be as indicated in Table IV. The metric would be represented by:

$$W_i = TF*IDF = Tf_i*idf_i = (1+\log Tf_{i,d})*\log \frac{N}{df_i} \quad (16)$$

The terms of the functions have been explained above. We obtain the weighting of the attributes (terms) by considering the function (16) above of which the outcomes are indicated in Table IV.

E. Term Importance

Jiao et al. established that "a classic way to assess the importance of a term is the so-called *tf-idf* (term frequency - inverse document frequency) term weighting scheme [49]". They further indicated that the term importance "is based on two assumption:

a) idf assumption: rare terms are more informative than frequent terms,

b) tf assumption: multiple occurrences of a term in a query document are more relevant than single occurrence [49].

After sorting the outcomes of the computations of the weighting in Tf*idf we are able to arrange in order of which attribute is more important than the others.

F. Euclidean Distance based Similarity

Past efforts [32] have showed that Euclidean Distance Geometry could "improve the authentication in digital identity management system and particularly improve the security in digital financial services".

The Euclidean distance between two points or terms (t_1 and t_2), from a corpus, in a two dimensional space is represented by the function.

$$d_{t_1,t_2} = \sqrt{\sum_{i=1}^{n}(t_{1i}-t_{2i})^2} \quad (17)$$

VI. Results

A. Term Frequencies (TF*IDF) in Proposed Metrics

Table V shows the index document frequencies (IDF) in our term weighting function.

B. Weighted Identity Attributes

Table VII shows the rating of the terms on which weighting has been applied. This rating indicates which identity attributes are most important in identifying a digital identity claimant against online interests in this corpus. We are interested to see which identity attributes are key in identifying an identity claimant.

C. Model Based on Cosine Similarity Measure

In order to demonstrate the effectiveness of our proposed model, we would need to apply our model on the dataset which considered the weighting of the attributes. The results of these metrics have been recorded in Tables VIII, IX, and X.

TABLE IV. TERM FREQUENCIES ON TEN DOCUMENTS FOR THE METRICS (ZAMBIAN FIGURES)

ATTRIBUTE	$Tf_i = 1 + \log Tf_{i,d}$									
	d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8	d_9	d_{10}
First name	1.6990	1.6990	1.6021	1.3010	1.6021	1.6021	1.3010	1.4771	1.0000	1.3010
Middle name	1.6990	1.6990	1.6021	1.3010	1.6021	1.6021	1.3010	1.4771	1.0000	1.3010
Last name	1.6990	1.6990	1.6021	1.3010	1.6021	1.6021	1.3010	1.4771	1.0000	1.3010
Date of Birth	0.0000	1.6990	1.3010	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
Place of Birth	0.0000	1.4771	1.4771	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Race	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Gender	0.0000	1.4771	1.4771	0.0000	1.3010	1.3010	0.0000	0.0000	1.0000	0.0000
Home address	1.0000	1.0000	1.3010	1.4771	1.6021	1.0000	1.4771	0.0000	1.0000	1.4771
House Number	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
Home telephone number	1.0000	0.0000	0.0000	1.0000	1.0000	1.0000	1.0000	0.0000	0.0000	0.0000
ID Number	1.0000	1.0000	1.0000	0.0000	1.0000	1.0000	1.0000	0.0000	1.0000	0.0000
issuing authority	1.0000	0.0000	0.0000	1.0000	1.0000	1.0000	0.0000	1.0000	1.0000	1.0000
Expiry date	0.0000	1.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Home email address	0.0000	0.0000	0.0000	1.0000	1.0000	1.0000	1.0000	0.0000	1.0000	0.0000
Work address	1.0000	1.0000	0.0000	1.3010	1.6021	1.0000	0.0000	0.0000	1.0000	1.4771
Work telephone number	1.0000	0.0000	0.0000	1.0000	1.0000	1.0000	1.0000	0.0000	1.0000	0.0000
Work email address	0.0000	0.0000	0.0000	1.0000	1.0000	1.0000	1.0000	0.0000	1.0000	0.0000
Bank account details	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
Height	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

TABLE V. INVERSE FUNCTION FOR THE TF*IDF WEIGHTING (ZAMBIAN FIGURES)

ATTRIBUTE	Total No. of docs	$idf_i = \log \frac{N}{df_i} = \log N - \log df_i$									
	N	d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8	d_9	d_{10}
First name	10	0.30103	0.30103	0.39794	0.69897	0.39794	0.39794	0.69897	0.52288	1.00000	0.69897
Middle name	10	0.30103	0.30103	0.39794	0.69897	0.39794	0.39794	0.69897	0.52288	1.00000	0.69897
Last name	10	0.30103	0.30103	0.39794	0.69897	0.39794	0.39794	0.69897	0.52288	1.00000	0.69897
Date of Birth	10	0.00000	0.30103	0.69897	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000
Place of Birth	10	0.00000	0.52288	0.52288	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Race	10	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Gender	10	0.00000	0.52288	0.52288	0.00000	0.69897	0.00000	0.00000	0.00000	1.00000	0.00000
Home address	10	1.00000	1.00000	0.69897	0.52288	0.39794	1.00000	0.52288	0.00000	1.00000	0.52288
House Number	10	1.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000
Home telephone number	10	1.00000	0.00000	0.00000	1.00000	1.00000	1.00000	1.00000	0.00000	0.00000	0.00000
ID Number	10	1.00000	1.00000	1.00000	0.00000	1.00000	1.00000	1.00000	0.00000	1.00000	0.00000
issuing authority	10	1.00000	0.00000	0.00000	1.00000	1.00000	1.00000	0.00000	1.00000	1.00000	1.00000
Expiry date	10	0.00000	1.00000	1.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Home email address	10	0.00000	0.00000	0.00000	1.00000	1.00000	1.00000	1.00000	0.00000	1.00000	0.00000
Work address	10	1.00000	1.00000	0.00000	0.00000	0.39794	1.00000	0.00000	0.00000	1.00000	0.52288
Work telephone number	10	1.00000	0.00000	0.00000	1.00000	1.00000	1.00000	1.00000	0.00000	1.00000	0.00000
Work email address	10	0.00000	0.00000	0.00000	1.00000	1.00000	1.00000	1.00000	0.00000	1.00000	0.00000
Bank account details	10	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000
Height	10	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

TABLE VI. TF*IDF WEIGHTING OF THE IDENTITY ATTRIBUTES ON TEN DOCUMENTS (ZAMBIAN FIGURES)

ATTRIBUTE	$W_{i,d}=TF_i * IDFi = Tf_i \, X \, \log \frac{N}{idf_i}$									
	d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8	d_9	d_{10}
First name	0.511441	0.511441	0.637524	0.909381	0.637524	0.637524	0.909381	0.772355	1.000000	0.909381
Middle name	0.511441	0.511441	0.637524	0.909381	0.637524	0.637524	0.909381	0.772355	1.000000	0.909381
Last name	0.511441	0.511441	0.637524	0.909381	0.637524	0.637524	0.909381	0.772355	1.000000	0.909381
Date of Birth	0.000000	0.511441	0.909381	0.000000	0.000000	0.000000	0.000000	0.000000	1.000000	0.000000
Place of Birth	0.000000	0.772355	0.772355	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Race	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Gender	0.000000	0.772355	0.772355	0.000000	0.909381	0.000000	0.000000	0.000000	1.000000	0.000000
Home address	1.000000	1.000000	0.909381	0.772355	0.637524	1.000000	0.772355	0.000000	1.000000	0.772355
House Number	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	1.000000
Home telephone number	1.000000	0.000000	0.000000	1.000000	1.000000	1.000000	1.000000	0.000000	0.000000	0.000000
ID Number	1.000000	1.000000	1.000000	0.000000	1.000000	1.000000	1.000000	0.000000	1.000000	0.000000
issuing authority	1.000000	0.000000	0.000000	1.000000	1.000000	1.000000	0.000000	1.000000	1.000000	1.000000
Expiry date	0.000000	1.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Home email address	0.000000	0.000000	0.000000	1.000000	1.000000	1.000000	1.000000	0.000000	1.000000	0.000000
Work address	1.000000	1.000000	0.000000	0.000000	0.637524	1.000000	0.000000	0.000000	1.000000	0.772355
Work telephone number	1.000000	0.000000	0.000000	1.000000	1.000000	1.000000	1.000000	0.000000	1.000000	0.000000
Work email address	0.000000	0.000000	0.000000	1.000000	1.000000	1.000000	1.000000	0.000000	1.000000	0.000000
Bank account details	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	1.000000	0.000000
Height	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

TABLE VII. LISTING OF IMPORTANCE OF THE IDENTITY ATTRIBUTES (ZAMBIAN FIGURES)

ATTRIBUTES	Term (Tf_i)										$T F_r * IDF_r$
	D1: Tf_1	D2: Tf_2	D3: Tf_3	D4: Tf_4	D5: Tf_5	D6: Tf_6	D7: Tf_7	D8: Tf_8	D9: Tf_9	D10: Tf_{10}	Total	$\sum_{i=1}^{n} Tf_i \, X \, log \frac{N}{idf_i}$
Home address	1	1	2	3	4	1	3	0	1	3	19	7.86397063
First name	5	5	4	2	4	4	2	3	1	2	32	7.43595130
Middle name	5	5	4	2	4	4	2	3	1	2	32	7.43595130
Last name	5	5	4	2	4	4	2	3	1	2	32	7.43595130
ID Number	1	1	1	0	1	1	1	0	1	0	7	7.00000000
issuing authority	1	0	0	1	1	1	0	1	1	1	7	7.00000000
Work telephone number	1	0	0	1	1	1	1	0	1	0	6	6.00000000
Work address	1	1	0	2	4	1	0	0	1	3	13	5.40987908
Home telephone number	1	0	0	1	1	1	1	0	0	0	5	5.00000000
Home email address	0	0	0	1	1	1	1	0	1	0	5	5.00000000
Work email address	0	0	0	1	1	1	1	0	1	0	5	5.00000000
Gender	0	3	3	0	2	2	0	0	1	0	11	3.45409156
Date of Birth	0	5	2	0	0	0	0	0	1	0	8	2.42082187
House Number	1	0	0	0	0	0	0	0	0	1	2	2.00000000
Expiry date	0	1	1	0	0	0	0	0	0	0	2	2.00000000
Place of Birth	0	3	3	0	0	0	0	0	0	0	6	1.54471062
Bank account details	0	0	0	0	0	0	0	0	1	0	1	1.00000000
Race	0	0	0	0	0	0	0	0	0	0	0	0.00000000
Height	0	0	0	0	0	0	0	0	0	0	0	0.00000000
Sum	**22**	**30**	**24**	**16**	**28**	**22**	**14**	**10**	**13**	**14**	**193**	

D. Verification of Ownership

For the purposes of verification of ownership of the attributes by an online user, we will assume that the object of ownership is the user of document 2 from our corpus of ten documents. Document 2 was purposed to capture attributes of a people who would apply for residence permit. It is only an individual who has entered responses that match the attributes of the specific individual that would be said to be said to be uniquely similar. For the sake of assessment of key attributes, we would consider the attributes involved in identifying the digital identity of our object and compare with the other attributes from the other nine (9) documents. We are going to look at the attributes of the second document and compare them to each of the documents of the nine other documents, respectively. Using our proposed model of the Cosine Similarity measure we would then observe the performance on similarity of the attributes of the second document to those of the other nine.

E. Verification Based on Term Frequencies

We have the following vectors from the Term Frequencies of the attributes of the 10 documents of the corpus:

i. Airspace (D1): Tf1 = D2

= (5, 5, 5, 5, 3, 0, 3, 1, 0, 0, 1, 0, 1, 0, 1, 0, 0, 0, 0)

ii. Residence Permit (D2): Tf2 = D1

= (5, 5, 5, 0, 0, 0, 0, 1, 1, 1, 1, 1, 0, 0, 1, 1, 0, 0, 0)

iii. Visiting Visa (D3): Tf3 = D3

= (4, 4, 4, 2, 3, 0, 3, 2, 0, 0, 1, 0, 1, 0, 0, 0, 0, 0, 0)

iv. Consent Form (D4): Tf4 = D4

= (2, 2, 2, 0, 0, 0, 0, 3, 0, 1, 0, 1, 0, 1, 2, 1, 1, 0, 0)

v. Farm Smallholding (D5): Tf5 = D5

= (4, 4, 4, 0, 0, 0, 2, 4, 0, 1, 1, 1, 0, 1, 4, 1, 1, 0, 0)

vi. Residential Land (D6): Tf6

= (4, 4, 4, 0, 0, 0, 2, 1, 0, 1, 1, 1, 0, 1, 1, 1, 1, 0, 0)

vii. Aquaculture Fund (D7): Tf7

= (2, 2, 2, 0, 0, 0, 0, 3, 0, 1, 1, 0, 0, 1, 0, 1, 1, 0, 0)

viii. Borehole Form (D8): Tf8

= (3, 3, 3, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0)

ix. Health Prof Council (D9): Tf9

= (1, 1, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1, 0, 1, 1, 1, 1, 1, 0)

x. Immovable Property (D10): Tf10

= (2, 2, 2, 0, 0, 0, 0, 3, 1, 0, 0, 1, 0, 0, 3, 0, 0, 0, 0)

Replacing the variables of the documents in our model, we let the documents to be identified by d1, d2, …, d10. We then apply our model:

Similarity = $S(X,Y) = Cos(\theta) = Cos(X,Y)$

$$= \frac{X * Y}{\|X\|\|Y\|} = \frac{\sum_{i=1}^{n} X_i Y_i}{\sqrt{\sum_{i=1}^{n} X_i^2}\sqrt{\sum_{i=1}^{n} Y_i^2}}$$

1. For $S(D_2, D_1)$:

d2.d1 = (5, 5, 5, 5, 3, 0, 3, 1, 0, 0, 1, 0, 1, 0, 1, 0, 0, 0, 0)*

(5, 5, 5, 0, 0, 0, 0, 1, 1, 1, 1, 1, 0, 0, 1, 1, 0, 0, 0) = ((5x5) +(5x5)+(5x5)+(5x0)+(3x0)+(0x0)+(3x0)+(1x1)+(0x1)+ (0x1)+(1x1)+(0x1)+(1x0)+(0x0)+(1x1)+(0x1)+(0x0)+(0x0)+(0 x0)) = 78

This follows that

$D_2{*}D_i$	$d_2{*}d_1$	$d_2{*}d_2$	$d_2{*}d_3$	$d_2{*}d_4$	$d_2{*}d_5$	$d_2{*}d_6$	$d_2{*}d_7$	$d_2{*}d_8$	d_{2*9}	$d_2{*}d_{10}$
Outcome	78	122	92	35	75	69	34	45	26	36

$\|d_2\| = \sqrt{5^2+5^2+5^2+5^2+3^2+0^2+3^2+1^2+0^2+0^2+1^2+0^2+1^2+0^2+1^2+0^2+0^2+0^2+0^2} = 122$

$\|d_1\| = \sqrt{5^2+5^2+5^2+0^2+0^2+0^2+0^2+1^2+1^2+1^2+1^2+1^2+0^2+0^2+1^2+1^2+0^2+0^2+0^2} = 82$

Therefore,

Similarity = $S(d_2,d_1) = Cos(d_2,d_1) = \frac{d_2{*}d_1}{\|d_2\|\|d_1\|} = \frac{78}{122\,x\,82} = \underline{0.007797}$

It follows that for the rest of the computations we have

$\|d_i\|$	$\|d_1\|$	$\|d_2\|$	$\|d_3\|$	$\|d_4\|$	$\|d_5\|$	$\|d_6\|$	$\|d_7\|$	$\|d_8\|$	$\|d_9\|$	$\|d_{10}\|$
Outcome	82	122	76	30	90	60	26	28	13	32

2. For $S(D_2, D_2)$:

$S(d_2,d_2) = Cos(d_2,d_2) = \frac{d_2{*}d_2}{\|d_2\|\|d_2\|} = \frac{122}{122\,x\,122} = 0.008197$

3. For $S(D_2, D_3)$:

$S(d_2,d_3) = Cos(d_2,d_3) = \frac{d_2{*}d_3}{\|d_2\|\|d_3\|} = \frac{92}{122\,x\,76} = 0.009922$

4. For $S(D_2, D_4)$:

$S(d_2,d_4) = Cos(d_2,d_4) = \frac{d_2{*}d_4}{\|d_2\|\|d_4\|} = \frac{92}{122\,x\,76} = 0.009563$

5. For $S(D_2, D_5)$:

$S(d_2,d_5) = Cos(d_2,d_5) = \frac{d_2{*}d_5}{\|d_2\|\|d_5\|} = \frac{75}{122\,x\,90} = 0.006831$

6. For $S(D_2, D_6)$:

$S(d_2,d_6) = Cos(d_2,d_6) = \frac{d_2{*}d_6}{\|d_2\|\|d_6\|} = \frac{69}{122\,x\,60} = 0.009426$

7. For $S(D_2, D_7)$:

$S(d_2, d_7) = Cos(d_2, d_7) = \frac{d_2 * d_7}{\|d_2\|\|d_7\|} = \frac{34}{122 \ x \ 26} = 0.010719$

8. For $S(D_2, D_8)$:

$S(d_2, d_8) = Cos(d_2, d_8) = \frac{d_2 * d_8}{\|d_2\|\|d_8\|} = \frac{45}{122 \ x \ 28} = 0.013173$

9. For $S(D_2, D_9)$:

$S(d_2, d_9) = Cos(d_2, d_9) = \frac{d_2 * d_9}{\|d_2\|\|d_9\|} = \frac{26}{122 \ x \ 13} = 0.016393$

10. For $S(D_2, D_{10})$:

$S(d_2, d_{10}) = Cos(d_2, d_{10}) = \frac{d_2 * d_{10}}{\|d_2\|\|d_{10}\|} = \frac{36}{122 \ x \ 32} = 0.009221$

Sorting the Cosine measure of the outcome that was calculated based on the Term frequencies of the documents di, d2, d3,…,d10 will give us the following:

It was observed that using term frequencies in our computations yields a result where the metrics using Cosine similarity measure gives a notable result. Comparing a document to itself in the computations yields a result third on the table as shown in Table VIII; this implies that the document is far from being identical to itself. This is clear indication that using term frequencies includes errors from the documents, which would include noise and other errors. Using standardized data helps in improving accuracy of results.

We therefore standardize the data using term weights and repeat the computations as above and record the results. The results are reflected in Table IX.

TABLE VIII. RESULTS ON UN-WEIGHTED DATA ON THE COSINE MEASURE

Rating	Function	Item	How close is the document to the object (D_2)?
1	S(d2,d5)	Document 2 compared to Document 5	0.006830601
2	S(d2,d1)	Document 2 compared to Document 1	0.007796881
3	S(d2,d2)	Document 2 *compared to itself*	0.008196721
4	S(d2,d10)	Document 2 compared to Document 10	0.009221311
5	S(d2,d6)	Document 2 compared to Document 6	0.00942623
6	S(d2,d4)	Document 2 compared to Document 4	0.009562842
7	S(d2,d3)	Document 2 compared to Document 3	0.009922347
8	S(d2,d7)	Document 2 compared to Document 7	0.010718789
9	S(d2,d8)	Document 2 compared to Document 8	0.013173302
10	S(d2,d9)	Document 2 compared to Document 9	0.016393443

F. Verification based on Term Weights

We have the following weights of the ten documents:

D_2*D_i	d_2*d_1	d_2*d_2	d_2*d_3	d_2*d_4	d_2*d_5	d_2*d_6	d_2*d_7	d_2*d_8	d_2*d_9	d_2*d_{10}
Outcome	3.784715	6.239353	5.545708	2.167639	3.955580	3.978167	3.167639	1.185042	5.818119	2.939995

We also have

$\|d_i\|$	$\|d_1\|$	$\|d_2\|$	$\|d_3\|$	$\|d_4\|$	$\|d_5\|$	$\|d_6\|$	$\|d_7\|$	$\|d_8\|$	$\|d_9\|$	$\|d_{10}\|$
Outcome	7.784715	6.239353	6.066322	8.077454	8.859156	9.219310	8.077454	2.789598	13.000000	5.673987

We therefore, have the following Cosine similarity measures from the data we have above:

1. For $S(D_2, D_1)$: $S(d_2, d_1) = Cos(d_2, d_1) = \frac{d_2 * d_1}{\|d_2\|\|d_1\|} = \frac{3.784715}{6.239353 \ x \ 7.784715} = 0.077920$

2. For $S(D_2, D_2)$: $S(d_2, d_2) = Cos(d_2, d_2) = \frac{d_2 * d_2}{\|d_2\|\|d_2\|} = \frac{6.239353}{6.239353x \ 6.239353} = 0.160273$

3. For $S(D_2, D_3)$: $S(d_2, d_3) = Cos(d_2, d_3) = \frac{d_2 * d_3}{\|d_2\|\|d_3\|} = \frac{5.545708}{6.239353 \ x \ 6.066322} = 0.146518$

4. For $S(D_2, D_4)$: $S(d_2, d_4) = Cos(d_2, d_4) = \frac{d_2 * d_4}{\|d_2\|\|d_4\|} = \frac{2.167639}{6.239353 \ x \ 8.077454} = 0.146518$

5. For $S(D_2, D_5)$: $S(d_2, d_5) = Cos(d_2, d_5) = \frac{d_2 * d_5}{\|d_2\|\|d_5\|} = \frac{3.955580}{6.239353 \ x \ 8.859156} = 0.071561$

6. For $S(D_2, D_6)$: $S(d_2, d_6) = Cos(d_2, d_6) = \frac{d_2 * d_6}{\|d_2\|\|d_6\|} = \frac{3.978167}{6.239353 \ x \ 9.219310} = 0.069158$

7. For $S(D_2, D_7)$: $S(d_2, d_7) = Cos(d_2, d_7) = \frac{d_2 * d_7}{\|d_2\|\|d_7\|} = \frac{3.167639}{6.239353 \ x \ 8.077454} = 0.062852$

8. For $S(D_2, D_8)$: $S(d_2, d_8) = Cos(d_2, d_8) = \frac{d_2 * d_8}{\|d_2\|\|d_8\|} = \frac{1.185042}{6.239353 \ x \ 2.789598} = 0.068085$

9. For $S(D_2, D_9)$: $S(d_2, d_9) = Cos(d_2, d_9) = \frac{d_2 * d_9}{\|d_2\|\|d_9\|} = \frac{5.818119}{6.239353 \ x \ 13.000000} = 0.071730$

10. For $S(D_2, D_{10})$: $S(d_2, d_{10}) = Cos(d_2, d_{10}) = \frac{d_2 * d_{10}}{\|d_2\|\|d_{10}\|} = \frac{2.939995}{6.239353 \ x \ 5.673987} = 0.083046$

Our main interest is to identify the text from the documents that would be the best identifier of the online user. The details of the digital object of an applicant of identity and verification, which in our case is represented by the identifying attributes, would need to accurately match attributes of verification. We therefore, consider the importance of attributes that is in the corpus of ten documents. Table IX shows the documents that are sorted in the order of importance; in this case, the documents would represent the applicants that are being subjected for verification by the process of authentication.

From Table IX, we see that it was important to normalize the Term frequencies from the documents so as to remove the errors from data. Without normalizing the data, we have the rating of the document affected to a point that the document compared to itself shows deficit in the content of terms. Removing the errors through normalization done by term weighting of the data from the corpus of the ten documents gives the rating where document 2 is compared to itself becomes first in rating. This is the natural expectation of the outcome of this process.

We have just established that when an online application or applications from multiple users for authentication, Cosine Similarity measure could help us to accurately identify who the true owner of the digital identity would be. This indicates that Cosine Similarity measure could be a very strong tool in information security to add another level in authentication. Coupled with other techniques, we could build a robust system in information security for Digital Identity management.

G. *Results on Metrics Model*

Table X shows the top ten identity attributes from the ten documents where TF*IDF term weighting was applied. Picking identity attributes that have been found to be higher in terms of weighting would help us identify the owner of the identity attributes for online identity claimant. Applying developed Identity Attribute Metrics, which was developed using the Cosine Similarity measure we obtain the following results:

TABLE IX. RESULTS ON USING WEIGHTED DATA ON THE PROPOSED MODEL

Rating	Function	Documents compared	How close is the document to the object (D_2) ?
1	d_2*d_2	Document 2 *compared to itself*	0.160273
2	d_2*d_3	Document 2 compared to Document 3	0.146518
3	d_2*d_{10}	Document 2 compared to Document 10	0.083046
4	d_2*d_1	Document 2 compared to Document 1	0.077920
5	d_2*d_9	Document 2 compared to Document 9	0.071730
6	d_2*d_5	Document 2 compared to Document 5	0.071561
7	d_2*d_6	Document 2 compared to Document 6	0.069158
8	d_2*d_8	Document 2 compared to Document 8	0.068085
9	d_2*d_7	Document 2 compared to Document 7	0.062852
10	d_2*d_4	Document 2 compared to Document 4	0.043010

TABLE X. LIST OF TOP TEN IDENTITY ATTRIBUTE FROM THE PROPOSED MODEL (ZAMBIAN FIGURES)

ATTRIBUTE	Term (Tf_i)										
	D1: Tf_1	D2: Tf_2	D3: Tf_3	D4: Tf_4	D5: Tf_5	D6: Tf_6	D7: Tf_7	D8: Tf_8	D9: Tf_9	D10: Tf_{10}	Total	T F_r*IDF_r $\sum_{i=1}^{n} Tf_i \, X \, log \frac{N}{idf_i}$
Home address	**1**	**1**	**2**	**3**	**4**	**1**	**3**	**0**	**1**	**3**	**19**	**7.86397063**
First name	**5**	**5**	**4**	**2**	**4**	**4**	**2**	**3**	**1**	**2**	**32**	**7.43595130**
Middle name	**5**	**5**	**4**	**2**	**4**	**4**	**2**	**3**	**1**	**2**	**32**	**7.43595130**
Last name	**5**	**5**	**4**	**2**	**4**	**4**	**2**	**3**	**1**	**2**	**32**	**7.43595130**
ID Number	**1**	**1**	**1**	**0**	**1**	**1**	**1**	**0**	**1**	**0**	**7**	**7.00000000**
issuing authority	**1**	**0**	**0**	**1**	**1**	**1**	**0**	**1**	**1**	**1**	**7**	**7.00000000**
Work telephone number	**1**	**0**	**0**	**1**	**1**	**1**	**1**	**0**	**1**	**0**	**6**	**6.00000000**
Work address	**1**	**1**	**0**	**2**	**4**	**1**	**0**	**0**	**1**	**3**	**13**	**5.40987908**
Home telephone number	**1**	**0**	**0**	**1**	**1**	**1**	**1**	**0**	**0**	**0**	**5**	**5.00000000**
Home email address	**0**	**0**	**0**	**1**	**1**	**1**	**1**	**0**	**1**	**0**	**5**	**5.00000000**
Work email address	0	0	0	1	1	1	1	0	1	0	5	5.00000000
Gender	0	3	3	0	2	2	0	0	1	0	11	3.45409156
Date of Birth	0	5	2	0	0	0	0	0	1	0	8	2.42082187
House Number	1	0	0	0	0	0	0	0	0	1	2	2.00000000
Expiry date	0	1	1	0	0	0	0	0	0	0	2	2.00000000
Place of Birth	0	3	3	0	0	0	0	0	0	0	6	1.54471062
Bank account details	0	0	0	0	0	0	0	0	1	0	1	1.00000000
Race	0	0	0	0	0	0	0	0	0	0	0	0.00000000
Height	0	0	0	0	0	0	0	0	0	0	0	0.00000000
Sum	**22**	**30**	**24**	**16**	**28**	**22**	**14**	**10**	**13**	**14**	**193**	

VII. Discussion

Testing the proposed Cosine Similarity measure as an Identity Attribute Metric Modeling is able to identify the document that uniquely has its identity attributes similar to itself as the highest rated and hence identify a claimant of the digital identity as the legitimate owner. This model would be able to identify the true owner claimant from one to multiple claimants of the digital identity. This would help in improving security on identifying the legitimate digital identity owner of a specific identity. Only such an owner should the given access to online assets, services, or attention.

It was observed that the identity attributes from the ISO list were based on physical identification of an individual claimant. The study showed that using Cosine Similarity measure, the legitimate owner of the digital identity would be uniquely identified with the top most score in the computations. To achieve this, mined text of digital identity would need to be normalized, in this case we used the term weight to normalize the data. The calculations with the model give best results on term weighted text. It was also observed that there was a set of digital attributes would score higher than others when we apply our model. After sorting the results of the model on the weighted text mined identity attributes, it was observed that the identity attributes that locate residence of a claimant was of paramount importance. It was equally observed that the identifying names of the claimant, national identification, economic activity, and contacts of the claimant were ranked high in the results of our computations.

VIII. Conclusion

The proposed model was able to identify the legitimate owner of the digital identity attributes and therefore, able to show who the false-identity online claimants were. The model was also able to identify the attributes that were key in identifying the legitimate owner of the claimed identity, in other words, the most important attributes to distinguish the legitimate owner from the false ones could be identified using this model. The identity attributes can be extracted from identity tokens by mining identity attribute text using data mining tools. The study has been able to develop an identity attribute metrics model using the Cosine Similarity distance measure and show that Cosine similarity measure can be used to quantify the identity attributes. The model has been tested on data that was mined and standardized using term weights; the outcome showed that the Cosine Similarity model can identify the unique owner of the digital identity attributes. The model also showed that it could identify a legitimate identity claimant from multiple claims. This model could add value to enhancing security in online activities by validating the true owner a digital identity. This model could also be used in multi modal tools for a robust online digital solution to arrest the challenges of online information security.

This research has developed an Identity Attribute Model that can be used to quantify the identity attributes from real space and cyber space. The model can identify the real owner of digital identity identify such a claimant from a number of identity claimants. This could therefore identify the bogus claimant of digital identity from the real ones. The outcome of this research could be augmented to already established techniques to form a robust multi modal tool of digital identity. The model would help to address the security challenge in identity management systems.

For future research interests, there is need to develop and implement the outcome of this research and build a multimodal solution. That solution would consolidate previous works in this area and come up with a single robust solution. Such a solution should recognize how much threat would be rid of in the online services and activities.

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Design Optimization of Power and Area of Two-Stage CMOS Operational Amplifier Utilizing Chaos Grey Wolf Technique

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Abstract*—Low Power Dissipation is an emerging challenge in the current electronics industry. Area shrinking has found the most prominent place and is the foundation of every constricted size in the utilization of CMOS circuits in Integrated Circuit Manufacturing. Functionality in terms of rapidity, dissipation of power, etc. are strongly influenced by the dimensions of transistors in many CMOS Integrated Circuits. The significant formulation parameters in CMOS circuit design to perform optimization of the above-mentioned parameters, and various techniques were projected earlier to a maximum extent possible. Latency, Power, and Dimension are significant parameters in the design of CMOS based IC design. Most analog circuit reduction in terms of size as parameter typically describes solitary or many objectives-controlled optimization issues. The eminent challenges with regards to size and power dissipation can be described as problems that are typically encountered under certain conditions. In this study, the design of a two-stage CMOS Differential Amplifier applying the nature-inspired Grey Wolf Algorithm for optimizing the area and power is utilized. To enhance the formulation terms concerning important considerations such as the amount incurred, strength, and functionality; a computerized formulation approach is used. This formulated design proposal will meet specifications such as positive and negative Slew Rate, Unity Gain Bandwidth and Phase Margin, etc. Chaos theory can be induced into the Grey Wolf Optimization Algorithm (CGWO) with the help of speeding global convergence metric i.e. Speed. The results obtained from CGWO are then analyzed with the functionality of other prevailing optimization techniques employed in the analog circuit sizing. Depending on the investigations, CGWO functions reduce the dimensions of the circuit and analyze the prevailing techniques by achieving a healthier rate of convergence and power dissipation with low value.

Keywords*—*CMOS; CGWO; optimization technique; operational amplifier; aspect ratio; power dissipation

I. Introduction

The development of expertise, compact devices, and special equipment have brought a tremendous change and enhanced an individual's style of living. Apart from this the prospects in the added formulation, characterize greater throughput and lengthier duration of a battery lifetime. Inexpensive memory, enormous processing strength, and rapid linking of packs are due to the determination of the semiconductor industry that has been following Moore's Law for more than a few decades. As the CMOS device becomes smaller, the design of a circuit increases in performance and dissipates low power [14]. IC's with 14nm fabrication techniques are used in the process of fabrication. IC Manufacturers are involved in researching the formulation of circuits in 7nm fabrication techniques. EDA based mechanisms support in identifying the best possible formulation techniques for reducing the power consumption adopting a strategy for reducing the dimension of gate sizing and choice of V_T. Engineers spend their considerable energy concentrating on the choice of software to formulate a devising strategy that satisfies formulation challenges. In addition to attaining the power objectives in the requirement, present electronic design software available in the market functions with a certain percentage of power reduction. It may not sufficiently explain the case where it originates in employing the strategy that satisfies the frequency needs utilizing reduced power in a global circumstance [13]. Mixed-Signal designs are growing rapidly in quantities such as a huge portion of fresh Integrated Circuits (IC's) that desire a need for connection to the outside world. With the incessant upsurge in the density and functionality of IC's, minimizing the dissipation of power has provoked a thoughtful challenge. A circuit engineer should be ready to face the challenge and be able to come up with the optimum design of the circuit. Simultaneously the inconsistent surge in various important technical characteristics might considerably upset the formulation and attainment of correct and least power consumed ICs in nanometer arrangement [11]. Gate Sizing Optimization is crucial to obtain timing closure and minimize the power dissipation of integrated circuits [12].

In the process of progressing towards technology, the chip manufacturing designers are subject to numerous technical obligations. Still, semiconductors consider power consumption and power dissipation as fundamental issues in the design of analog IC for the present scenario and may continue to do so for the future years. The latest problem that is being faced by the industry is dependability that comprises of production-connected disparities in addition to internal and external disturbances. The dissipation of power of a CMOS gate comprises two mechanisms i.e. stationary and active [16]. The stationary power dissipation is because of the movements of current in the supplies (VDD and GND) though devoid of switching process in the circuit. Because of a minor portion of the current that leaks through the reverse-biased junctions of the transistors, static power dissipation's non-conform to a perfect zero. The charging and discharging of the capacitive load have resulted in the dynamic power dissipation. During the changeover from low to high, the pMOS transistor(s) scatter energy and while from high to low changeover, the nMOS transistor(s) scatter energy. Static Power can be explained with a changeover of the gate in between ON-state and OFF-state with a given frequency. Power-Delay-Product (PDP) is utilized in an explanation of the dissipation of power [15].

Comprehensive system-on-a-chip is developed by incorporating assorted analog and digital circuits with the help of experts that are advancing in the field of VLSI. In a complete circuit, though the analog fragment takes up only a small proportion it has a greater complexity in devising better circuits because of the toughness that requires comprehensive expertise in the behavior of circuits. Computerized utilization in the selection of dimension strategy gets affected because of lengthier duration and greater complexity of formulation. This arises due to incompetent expert practitioners. This results in attracting greater challenges in computerized synthesis strategies of circuits. The formulation of processes depends on the structure and its parameters. The present study focuses on the design of circuits using parameters concentrating on the choice of parameters and finding the best solutions with the help of optimization techniques to enhance the functionality of pre-designed circuit structure [18].

In the design of analog ICs, the most important motivations i.e. Size -based methodology is explained here as follows: The first and foremost one explains substitution of search of tiresome and unstructured labor-intensive compensation by the instinctive formulation of parameters. In the second method, it helps to determine solutions to problems that are complex to formulate by hand. Preciseness, simplicity, generalization, sturdiness, and satisfactory duration are the parameters to be assessed for execution to improve the synthesis of the circuit for achieving good standards for approval. Apart from the tough challenges that are faced by the engineers, satisfying the designer's necessities for extremely controlled challenges and the capacity to attain exceedingly augmented outcomes are important motivations for greater functionality in the proper selection of dimensions for the integrated circuits. Using various parameter-based formulation techniques, methodologies, and tools which are established in recent years, some of them have achieved good market status. Many Integrated Circuit dimensioning issues have articulated with the view of optimizing either the single or multi-objective-controlled constraint. This constraint explains the reason for the reduction of power consumption commonly focused on certain issues e.g. It was found that gain was larger with certain threshold values [17].

The reduction in the dimension of IC's is performed by adopting or following diverse strategies depending on the expertise of the designers and on many of the optimization techniques [19]. The fundamental concept of knowledge dependent design is intended towards devise formulation of expressions in a quantity that provides functionality features and formulation parameters that are easily evaluated. The perception of an expertise-dependent selection of dimension methodology impacts the formulation expressions. Implementing tools for obtaining solutions concerning preciseness and sturdiness are often not satisfactory in tough circuits and contemporary techniques. This is due to the huge preliminary time needed to generate design tactics or expressions that could be a major disadvantage. Moreover, this complexity involves utilizing the energy in the selection of different techniques that are restricted towards a reduced group of circuit structures. By selecting the function optimizing techniques, the design strategy is modified to reduce the function and utilization of mathematical strategies to determine the best possible solutions. This type of technique is broadly recognized and accepted all over the world. Most prominently it is dependent on the definition of a functionality measurement within a repetitive optimization loop [20].

II. Literature Survey

Optimization of VLSI circuits needs evolutionary techniques because of the simplicity and ease of approach. In the paper proposed by Sarkar *et al*. (2018) [1], the aim of achieving this dimension is optimum and the purpose of obtaining reduced offset voltage in the formulation of two-step CMOS OP-amp is accomplished with the help of Whale Optimization Algorithm. The proposed design satisfying diverse formulation conditions like Slew Rate, Open Loop Gain, etc. will be considered as additional conditions in the design of the operational amplifier. To manage current disparity during the output stage of the Operational Amplifier, offset reduction is considered to be a significant need. Subsequently, by reformulating the Operational Amplifier in the usual CADENCE Virtuoso circuit simulator, technical outcomes of the process are confirmed. The results of simulated outcomes and the outcomes obtained through the Whale Optimization Technique are well identified. The outcomes derived through the proposed WOA are then analyzed with the functionality of some other techniques utilized in the previous research papers. It is observed that the WOA achieved better results for the circuit dimension with the lowest size in the design of CMOS Operational Amplifier for reduced offset as analyzed with other techniques. Based on the comparative analysis, it is found that WOA outclasses all the other techniques by achieving a faster convergence, least power dissipation and reduced offset.

For enhancing the cost-effectiveness in the formulation procedure of analog ICs, stability, and functionality, the computerized design procedures are employed. The occurrence of boundaries in the disturbance, the minimum strength of the signal at a circuit can be managed to a satisfactory level but it upsurges the difficulty of the circuit design. Optimization techniques consume a lot of time for finding the solutions and complex processes that encompass managing broader diversity of inconsistent limitations or design conditions and broader expanse of characteristics in the design process.

Work proposed by Singh *et al.*, (2018) [2] suggests overcoming the above-mentioned limitations by implementing Particle Swarm Optimization with an Aging Leader

(ALCPSO)-dependent formulation technique. Concurrent reduction of thermal noise and the dimension of the circuit was the prominent focus of the researchers in the proposed work. For achieving that, ALCPSO is utilized in exploring the solution inside the space that is provided for processing the conditions along with the characteristics that are useful in the formulation of the circuit. On the other hand, the established strategy for formulating the circuit includes reduction of distortion due to thermal effect as one of the prominent design conditions along with other conditions that are missing in the preceding computerized technique. The established technique aims at reducing the dimension such as length and breadth that consequently reduces the area of the circuit. The evaluation of the ALCPSO-design technique was carried out by utilizing MATLAB. To synthesize in the CADENCE tool with 0.18 µm parameters technique is used for examining the proposed technique by utilizing the ALCPSO method.

Most prevailing technologies utilized either Logical Effort (LE) strategy or individual optimization techniques for computerized selection of dimensions of the transistor for the CMOS logic circuits. A logic circuit is optimized only following the speed while it completely avoids power and dimension by the Logic Effort Strategy. A large amount of processing exertion is required while heuristic algorithms are utilized as the only individual technique for optimization purposes. Enforcing constraints on the dimensions of the transistors in such a way that it would help in reducing the strategical space satisfies the conditions of the destination.

In the paper proposed by Kunwar Singh *et al*., (2018) [3] the above challenges were overcome by employing latency factor of sensitivity depending on the theory of Logical effort methodology as devised by Alioto *et al*., to predict the maximum functioning speed of a logic circuit in addition to finding the maximum limit of the transistor's dimension. To confirm the efficiency of the recommended technique PVT investigation and Monte Carlo simulations were utilized.

For the formulation of optimal strategies for two of the normally utilized analog circuits, such as CMOS differential amplifier with current mirror load in CMOS, two-step Op-Amp, a hybrid population dependent meta-heuristic search technique called as Gravitational Search Algorithm (GSA) was incorporated along with Particle Swarm Optimization (PSO) (GSA–PSO) by Mallick *et al*., (2017) [4]. PSO and GSA belonged to the modest population dependent strong evolutionary technique, but on the other hand, they contain one of the issues i.e. sub-optimality. For the accomplishment of optimal strategies of two amplifier circuits, the formulated GSA–PSO dependent technique was utilized in overcoming this disadvantage confronted in PSO and the GSA techniques and was implemented by Mallick *et al*., in his research work. The dimensions of the transistors are optimized utilizing GSA–PSO in such a way that it reduces the dimensions engaged by circuits and enhances the design/functional characteristics in the circuits. For optimizing the dimensions of transistor sizes, several design constraints/functional characteristics are taken into consideration. To validate the dominance of GSA–PSO over the other optimization techniques by the speed of convergence, formulation constraints and functionality characteristics in the optimal formulation of the analog CMOS amplifier circuits, the simulation was performed, and comparative investigations were done. Some more issues and problems confronted by the research carried out by Mallick *et al*. had an appropriate adjustment in regulating characteristics by the GSA-PSO technique. Certain contradictory formulation/functionality characteristics were moderately mitigated with the help of frequent physical adjustments. To overcome the above-mentioned complex issues, utilization of Multi-objective optimization is preferred as a replacement.

For the quick selection of optimum dimensions of CMOS Analog Circuits utilization of the substitution modeling strategies along with a grouping of meta-heuristics was projected in the research work carried out by Garbaya *et al*., (2018) [5]. Utilization of meta-modeling techniques within an optimization loop and demonstrating the benefits as their primary motivation. They had taken into consideration the design of two CMOS analog circuits in addition to demonstrating techniques that permit the accomplishment of the selection of optimal dimensions. The traditional in - loop optimization strategy achieved the mentioned functions with minimum processing duration. The achieved outcomes depicted that the RBF-PSO technique permits in achieving outcomes as precise as the ones achieved by utilizing the traditional in-loop optimization strategy, but with a substantially minimized duration for the execution of the proposed technique.

The prominent reason for power dissipation is due to the power leakage in the circuit that is designed with the nanometer technique. The most utilized renowned technique in the minimization of Power leakage is the Input Vector Control (IVC). Because of the impact of stacking strategy that is utilized in IVC, this technique provides Leakage Power that will be minimum for the Minimum Leakage Vector (MLV) enforced as sources of the circuit under inspection.

To determine the leakage vector with a minimum value, Particle Swarm Optimization (PSO) technique was utilized in research work performed by Rani, and Latha (2016) [6]. The genetic Algorithm was also utilized to explore the Leakage Vector with the Minimum objective and analyzed with PSO concerning the number of steps utilized in the optimization. Simulation outcomes were observed and it demonstrated that PSO reliant technique performed superiorly in the determination of Leakage Vector using minimum value when compared with the GA method because PSO procedure utilizes the least quantity of duration of execution related to GA. PSO based Optimization technique in determining the leakage vector with minimum value and in the optimization of power leakage was proposed and utilized for the first time.

In the paper proposed by Azam *et al.*, (2016) [7], a methodology for simultaneous optimization was formulated for CMOS logic gates for power-and-noise margin and energy-and-noise-margin. The sizing parameter for functionality improvement of various gates had been extended to satisfy other figures of merit, such as dependability, power, and energy. By utilizing the examples of three and four input logic gates, they have explained how multiple yet contradictory formulation objectives can be obtained. For example, one of their high functionality gates showed power savings of more than 30% while minimizing the gate area by 39%. A significant stage of compromising the rise and fall times of outcome was also utilized in the optimization framework. Their formulated technique was expandable, and it could be utilized for optimizing greater logic blocks. Even though developing gate sizing methodology was motivated to enhance functionality, the present research discloses many other benefits of the methodology. The expandability of their methodology and the inspiring outcomes had made them examine complex and bigger CMOS circuits.

Opposition Dependent Harmony Search technique (OHS) was utilized in the research by Maji *et al*., (2015) [7] for the formulation of Differential Amplifier with CMOS Transistor in an optimum manner. With the help of rules such as memory rule, a pitch fine-tuning rule, and an initialization procedure, every answer in Harmony Memory (HM) produced provides the best outcome with the smallest possible error fitness in n-dimensional exploration spaces. Compromise in the investigation and taking advantage of the utilization of exploration space resulted in the Integration of various regulating characteristics using fundamental HS technique. The disadvantages of early convergence and sluggishness are reduced by utilizing the OHS technique in the formulation of CMOS Differential amplifier. SPICE simulation is implemented on optimized characteristics for assuring the dominance of OHS based strategy outcomes to the rate of convergence formulation criteria and motivations observed assure the dominance of the formulated OHS based technique over other optimization techniques in the formulation of designed amplifier in an optimal manner. Apart from showing dominance for the various parameters, the suggested technique delivers a reduction in dimension of the transistor along with enhanced gain and scatters power reduced in comparison with the observed existing researches.

For any circuit application, while manufacturing chip minimization area forms the fundamental objective in any circuit design procedure; the formulation phases encompass a simulated process for recognition that is performed repetitively for their effectiveness. For this motivation, the CAD algorithms provide a diverse solution based on the requirements and constraints formulated by the engineer. EDA tools help in the conception of impacts created by proposed algorithms over the functionality of circuit functionality in addition to the measurement of floor dimension engaged while designing the circuit.

The research work proposed by Swetha *et al*., (2015) [8] explains the impact of hybrid strategy for formulating the proposed circuit. The proposed work explains the impact of enforcing the navigation reliant aggregating techniques KL, FM for the circuits thus optimizing cells utilized by the Hybrid Genetic Algorithm (HGA).

For optimizing the analog IC, a constrained sparse modeling technique was implemented in the paper proposed by Tao *et al*., (2018) [9]. This paper described the collective benchmark circuit employments at gate level optimizing the dimensions of transistors utilizing evolution dependent GA technique. A segregation and deployment node in proper position and uniting the formulation phases of floor planning and segregation of nodes is performed by the proposed hybrid Genetic Algorithm. The outcomes recommend such a technique, on the formulation of circuits that offer possibilities of integrating the phases of physical design stages of partitioning with the deployment of nodes in addition to optimizing the dimension of the transistor in the formulation procedure.

For optimizing the analog circuits within the local formulation space, by efficiently employing convex semidefinite programming relaxation the above-mentioned prototypes are utilized. Formulated Prototype and optimizing strategy might rapidly converge towards an accurate solution for the design of analog IC's by utilizing mathematical samples as compared to the traditional techniques that fail in the proper functioning of the circuit. A limitation of an acyclic graph can be fulfilled by taking into consideration the GC-SPM. They were able to demonstrate it with the help of a group of scarce functionality representation. To achieve global optimum with least processing expenditure and memory utilization, optimization technique might complement with convex SDP relaxation technique. Their mathematical analysis established the effectiveness of the formulated strategy on performing comparative analysis with a traditional sparse POP strategy. With the help of transistor-level simulations, the toughness of the formulated optimization technique depending on GC-SPM was simulated. Effective strategies for minimizing the number of simulations needed to model the precise functionality or execution of every simulation with pronounced significance might analyze their upcoming investigation. Moreover, to optimize the enormous framework, they might prolong the formulated strategy in determining solutions for optimizing the issues of multi-objective nature and obtain Pareto Optimal fronts to separate the analog blocks.

Depending on the physical characteristics based on g_m / I_D as a guide for the optimization strategy of the power dissipated, the least value for the analog CMOS ICs is proposed by Girardi and Bampi (2006) [10]. ACM MOS bunched and solid model in the optimization loop is implemented with the help of the conventional layout tool LIT implements. To achieve the answers nearer to an optimum solution with solitary technique reliant on a curve and precise equations for the parameters such as transconductance and effective current within the complete functional areas is carried out with the help of the strategy utilized for computerized design within LIT and takes advantage of entire formulation space by using the simulated annealing optimizing procedure. This procedure contains an investigative equation that is incessant in the present conditions, comprising feeble and modest inversion utilized by the strong and bunched prototype that supports the best solutions and employment in an optimized manner. Benefits in limiting optimization strategy inside the power budget take pronounced significance for the transistor to have the least power consumption. Samples that depicted the optimization outcomes are achieved with LIT, leading to considerable power savings. The formulation of a folded cascade and a two-stage Miller Operational Amplifier was possible.

III. Problem Formulation

An optimization problem with constraints takes the subsequent arrangement:

$min_x\ f(x)$

Subjected to

$g(x) \geq 0$

$h(x) = 0$

$X_L \leq x \leq X_U$

The value of a function is optimized to be the objective function f(x). Here, g(x) and h(x) are the in-equivalence values with equivalence constraints. X_L and X_U are the limits of variables. While achieving the solution, certain conditions might fulfill the equivalence conditions. These constraints are known to be active constraints while others are known to be inactive constraints. The active constraints compose the active set.

Formulation of a circuit takes the following formats so that an op-amp could be devised as an optimization problem with constraints like subsequent statements.

$Min_x\ Area\ (x)$

Subject to

$Gain\ (x) \geq GAIN$

$Slew\ Rate > SLEW\ RATE$

$Unity\ Gain\ Bandwidth \geq UGB$

$Phase\ Margin \geq PHASE\ MARGIN$

$X_L \leq x \leq X_U$

The design variables x are the bias voltages and represent currents and dimensions of the device. The functions Gain, Slew Rate, etc. are considered as nonlinear functions in a certain or complete set of variables. Formulation conditions are marked in capital letters on the right-hand side of the conditions in equations [27].

Answers for certain problems in optimization are not well defined [21]. Equivalence conditions and in-equivalence conditions are characterized usually as numerical equivalence and in-equivalence expressions correspondingly for the problem of optimization. Parameter variations are to be satisfied in both classes of conditions. Deterministic techniques such as viable route strategy in addition to comprehensive gradient descent techniques are generated to determine solutions to limitation issues [22]. These techniques are not effective while considering real-time applications that comprise of structural optimization problems. To handle these complex conditional issues several metaheuristic algorithms are devised. These techniques intended towards the bearable velocity of convergence, improved accuracy, robustness and enhancement of functionality

IV. Proposed Methodology

The operational amplifier is an outstanding device out of the available electronic hardware. Operational amplifiers operate at several stages of multifaceted excellence that needs to be utilized in the process of recognizing capabilities ranging from a forthright DC inclination generation to swift improvements or isolation. Operation amps are the most widely employed construction hampers in Analog and Digital Electronic Circuits that are most normally employed as a portion of used electrical and logical devices [30].

In the formulation of a two-stage operational amplifier (op-amp), folded cascade Operational Trans-Conductance Amplifier (OTA), etc. the differential amplifier features a regular analog portion and takes the most prominent stage. Analog IC manufacturing technique is fundamentally decomposed into three important stages:

- Adoption of Proper circuit topology
- Optimized Sizing for the Device
- Extraction of proper Layout

The formulation procedure encompasses two prominent steps: conception of formulating technique and optimization of selected techniques. The visualization of the design is carried out with the help of recommending architecture to satisfy the provided conditions. The visualization step is usually carried out with the help of manual calculations to handle the spontaneous viewpoint required to satisfy the selections that must be followed. Considering the “First Cut” design; examining it and the optimization of the design technique is the subsequent step. The second step is usually performed with the help of computer simulation and can comprise of stimulus from conditional or procedural fluctuations.

The generation of proper physical formulation and the development of Low power Op-amp is our key focus. The characteristics of an ideal op-amp containing a single-ended output are listed as the ideal op-amp. It should have differential input, infinite voltage gain, infinite input resistance, zero output resistance. But in real circumstances, the above-mentioned parameters might not get satisfied. On the other hand, the functionality of the op-amp should be adequate for the good performance of the circuit and nearly achieve the parameters prescribed for ideal conditions when being applied to many applications. Every fresh evolution of the CMOS process establishes the formulation of op-amps that endures in bearing the additional conditions in such a way that the supply voltages and the channel length of the transistor are reduced [29].

It is possible to carry out the devising strategy of analog IC and the selection of proper dimensions with the help of skillful engineers and utilizing insight and knowledge. The exploration space intensifies, when the circuit complicatedness grows, and it is much complex to formulate analog ICs. Therefore, the formulation procedure takes a long time for engineers to achieve closer ideal parameters. So, engineers rely more on optimizing techniques. In the procedure of formulation, the optimal formulation of analog components is a serious challenge. Appropriate selection of device dimension is very significant for dependable, effective and accurate CMOS Analog ICs formulation. Device dimensions and the inter-association between the Aspect Ratios of MOS transistors provide the assurance of the exploration space in the devising strategy of CMOS Analog IC. Analog IC devising strategy and proper selection of circuit dimensions and selection of efficient optimization strategies is an important prerequisite.

In 2014, Mirjalili *et al*. introduced an influential and powerful meta-heuristic nature-inspired optimization technique, known as Grey Wolf Optimization (GWO) [23] that relies upon grading in the community, leadership profile in addition to natural hunting performance of the mentioned animal community. The Grey Wolf Optimization meta-heuristic techniques contain the capability of circumventing local optima stagnation to a certain amount [27] and reliant on the generation of the population. Along with the above-mentioned advantage, it has a superior convergence rate in the achievement of the optimal solution that navigates automatically towards the optimal solution by powerfully exploiting the search space. Nevertheless, the utilization of a global search technique was not exploited comprehensively. Thus, in some cases, GWO flops in the identification of globally best solution in certain circumstances. Because of the above-mentioned fact, some of the issues cannot be managed by GWO in a competent manner [28].

Chaos theory was enforced in various applications by the progression of non-linear dynamics [24]. It also efficiently combines with the optimization strategies [25]. Various Meta-heuristic Optimization techniques along with the effective combination of Chaos theory were being utilized which improve the performance to a greater extent [26].

A. Design Specification and Design Steps

Formulation conditions take the maximum share of significance in formulating any analog ICs. The pictorial representation of a two-stage Operational Amplifier is presented in Fig. 1. The conditions provided in the design of a differential amplifier are as follows:

1) Slew Rate (SR) in V/μs,

2) Small-signal DC voltage gain (Av) in dB,

3) Cut-off frequency (f-3dB) in kHz,

4) Maximum Input Common-Mode Range (ICMR) (VICMR (max)),

5) Minimum ICMR (VICMR (min)) in V,

6) Power dissipation (Pdiss) in mw

7) Phase Margin in dB

Channel Width and Channel Length of MOS which determines the aspect ratios(S) of MOS transistors, Load Capacitance (CL) in pF and Compensation Capacitance (CC) in pF are measured to be formulation variables of the differential amplifier. Various Phases of Formulation are employed by utilizing a connection following the conditions provided for the design. For achieving the appropriate channel width and Channel Length which helps in the selection of aspect ratios of entire MOS transistors is focused at reducing the area engaged by all the MOS transistors in addition to the reduction of total power dissipation, it is implied that framing of Objective Function or Cost function will be most compulsory one.

8) Design Strategies adopted in the formulation of proposed Amplifier Circuit

Steps utilized in the design of the proposed circuit that is differential amplifier utilized in the Operational amplifier circuit will be provided by calculating according to (1).

Let $L_1 = L_2$, $L_3 = L_4$, $L_5 = L_6$ (1)

Based on the anticipated phase margin, picked up least possible values for *Cc*, i.e. for a 60° phase margin, it is assumed that Right Half Plane (RHP) zero (z) is more than ten times to unity gain bandwidth (UGB).

$z \geq 10\text{UGB}$ and hence assume that $C_c \geq 0.22C_L$ (2)

The value of I_{D5} is found out to meet the Slew Rate as shown in (3).

$$\textit{Slew Rate} = \frac{I_{D5}}{C_L} \quad (3)$$

The minimum value of the tail current (I_5) is calculated as shown in (4).

$$I_5 = \text{Slew Rate} * C_c \quad (4)$$

Tail current (I_{SS}/I_5) can be calculated as in (5).

$$2 * \pi * f_T = \frac{2 * I_{SS}}{(V_{GS} - V_{TH})^{\frac{1}{C_L}}} \quad (5)$$

Where I_{ss} is the tail current. The value of the Aspect ratio for fifth transistor S_5 is computed from the least input voltage. The value of V_{DS5} (sat) and S_5 is calculated subsequently as shown in (6) and (7).

$$V_{DS5}(\text{sat}) = V_{IN}(\text{min}) - V_{ss} - \sqrt{\frac{I_5}{\beta_1}} - V_{T1}(\text{max})100\text{ mv} \quad (6)$$

$$S_5 = \frac{2 * I_5}{K'_5 [V_{DS5}(sat)^2]} \quad (7)$$

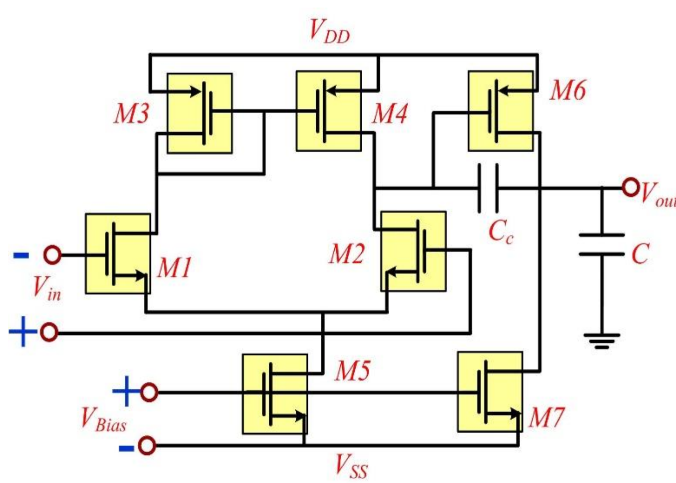

Fig 1. Schematic of Proposed Amplifier.

The value of S_6 is calculated by making the second pole (p2) equivalent to the product of 2.2 * Gain Bandwidth Product and making an assumption by which $V_{SG4} = V_{SG6}$ as shown in (8) and (9).

$$I_6 = (S_6 \,|S_4\,)I_4 \quad (8)$$

For balancing, I_6 must equal $I_7 = \frac{S_6}{S_7} = \frac{2*S_7}{S_4}$ (9)

Calculating the aspect ratio of the first transistor that is equal to the second transistor to meet the voltage gain $\frac{W_1}{L_1} = \frac{W_2}{L_2}$

where first stage gain is given as in (10).

$$A_{V1} = g_{m1} * R_{OUT} = \frac{g_{m1}}{g_{ds2} + g_{ds4}} = \frac{2}{\lambda_n + \lambda_p}\left(\sqrt{\frac{K_n' * W_1}{I_{D5} * L_1}}\right) \quad (10)$$

The second Stage gain is obtained as in (11), (12), (13) & (14).

$$\boldsymbol{A_{V2}} = \frac{g_{m6}}{g_{ds6} + g_{ds7}} = \frac{g_{m6}}{I_6\,(\lambda_6 + \lambda_7)} \quad (11)$$

$$g_{m6} = 2.2 * g_{m2}\left(\frac{C_L}{C_c}\right) \text{ and } S_6 = S_4 * \left(\frac{g_{m6}}{g_{m4}}\right) \quad (12)$$

$$I_6 = \frac{g_{m6}^2}{2 * K_6' * S_6} \quad (13)$$

$$f_{-3dB} = \frac{1}{R_{OUT} * C_L} \quad (14)$$

Aspect Ratio of the third Transistor is calculated that is equal to the fourth transistor $\frac{W_3}{L_3} = \frac{W_4}{L_4}$ to determine and meet the upper Limit of ICMR as shown in (15) and (16).

$$V_{lc}\text{ (max)} = V_{DD} - V_{SG3} + V_{in1} \quad (15)$$

$$\frac{W_3}{L_3} = \frac{2 * I_{D5}}{K_p'\,(V_{GS3} + V_{tp})^2} = \frac{W_4}{L_4} \quad (16)$$

Aspect Ratio of Fifth Transistor is estimated $\frac{W_5}{L_5} = \frac{W_6}{L_6}$ that is equal to the sixth transistor to find and meet the lower limit of ICMR as given in (17) and (18).

$$V_{lc}\,(min) = V_{ss} + V_{Ds5}(sat) + V_{Gs1} = V_{ss} + V_{Ds5}(sat) + V_{Gs2} \quad (17)$$

$$\frac{W_5}{L_5} = \frac{2 * I_{D5}}{K'_n\,[V_{DS5}\,(sat)^2]} = \frac{W_6}{L_6} \quad (18)$$

I_{D5} is measured to meet the power dissipation P_{diss} where

$$P_{diss} = I_{D5}\,(V_{DD} + |V_{SS}|) \quad (19)$$

$$P_{diss} = (I_5 + I_6)\,(V_{DD} + |V_{SS}|) \quad (20)$$

Right Half Plane Zero (RHP zero)

$$z_1 = \frac{g_{m6}}{C_c} \quad (21)$$

The calculated root is very unwanted as this one increases the amplitude while declining the phase leading left-half plane pole as in (22).

$$p_1 = -\frac{(g_{ds2} + g_{ds4}) * (g_{ds6} + g_{ds7})}{g_{m6} * C_c} \quad (22)$$

This root completes the anticipated compensation Left half-plane output pole $p_2 = -\frac{g_{m6}}{C_L}$ (23)

To fulfill the phase margin, the calculated pole must be greater than the unity-gain bandwidth 60 Degree phase Margin as given in (24).

$$g_{m6} = 2.2 * g_{m2}\left(\frac{C_L}{C_O}\right) \quad (24)$$

For Optimization, the design of Objective Function is the most crucial stage and optimization algorithm will maximize or minimize the objective function called Cost Function depending on the constraints and the focus primarily is on determining the best feasible solution by satisfying all the provided conditions. Objective Function may be single or multi-objective [31].

In equation (25), Objective function or Cost Function can be calculated as:

$$\text{OF (or) CF} = \sum_{i=1}^{n}(W_i * L_i) \quad (25)$$

Where *n* represents the number of transistors utilized in the formulation of the total circuit, 'W' represents the width of the MOS transistor and L represents the length of the MOS transistor. The primary motivation lies in optimizing the value of *Objective Function* which has to be smaller than 180 μm^2 for the provided circuit configuration.

B. Grey Wolf Optimization

Mirjalili *et al.* [23] introduced and established The Grey Wolf Optimization (GWO) technique that exploits the behavior of headship grading and chasing and attacking strategy of the prey by grey wolves in wildlife. These animals have their place to the Canidae family that are taken into consideration and takes its position as prowler in the highest point of the food cycle. Their social leadership grading is divided into alpha (α), beta (β), delta (Δ) and omega wolves (Ω).

The grey wolves contain various types of clusters intended towards diverse activities like framing a cluster to accommodate and pursue the target. Grey wolves that take the position as uppermost status in the arrangement are known to be alpha category wolves and these will be measured as the front runner in the bunch. These categories of wolves are involved in policymaking, power attacking, chasing, napping and period to awaken, etc.

Category of the above-mentioned animals that take a position as the second level in the ranking order is known to be beta category and are second only to the alpha category. Beta Category supports the alpha category in the policy composting process. In circumstances where alpha category wolves are becoming aged and unfit to lead the group or expire suddenly, then beta wolves take up the position as leading the group in the place of alpha wolves.

The wolves that take the position as third in the order of the hierarchy are supposed to be called as the omega kind of wolves. They continuously track the commands provided by the dominant category of wolves, alpha and beta wolves in the ranking. Thus, Omega sort of wolves is compulsorily required in maintaining the superiority assembly in the order [32] and maintain discipline among the group.

The category of wolves that is not fitting itself in the alpha, beta and omega class of the mentioned animals will be determined as delta class of wolves. Delta categories incessantly obey the alpha and beta categories of wolves, on the other hand, try to dominate the omega category of wolves.

All categories of wolves are divided into five fundamental kinds of wolves based on their operation and functionality. They are listed as following (i) Scouts, (ii) Sentinels, (iii) Elders, (iv) Hunters and (v) Caretakers.

Scouts are accountable intended towards the inspection of the borders in addition to conveying the cluster about the threat. Sentinels are intended towards assuring the security of the cluster. The elder category of wolves takes up the position as knowledgeable wolves and the knowledge provided by them is utilized for ambushing the target or identifying the elements. Functions such as Hunting the target and offering the food for the cluster are taken up by the Hunters. Lastly, Caretakers are accountable for taking care of the fragile, hailing and wounded animals. To explain the hunting strategy of the mentioned animals four diverse phases are utilized.

1) Searching for prey: Exploration procedure started with any arbitrary way of beginning of candidate solutions from the examination space. They deviate from one another to probe the target and congregate after they identify it.

2) Encircling prey: After identification of the target, grey wolves enclose the target. Encircling conduct might be signified as specified below in (26) and (27).

$$\vec{E} = |\vec{O}.\overrightarrow{Xp}(i) - \vec{X}(i)| \tag{26}$$

$$\vec{X}(i+1) = \vec{X}_p(i) - \vec{B}.\vec{E} \tag{27}$$

Here recent iteration is characterized by $\vec{B}$ and $\vec{O}$. These are the coefficient vectors. $\vec{B}$ is utilized in upholding the distance from search agents to the target. $\vec{O}$ signifies hindrances in the attacking route undertaken by animals whereas tactics in reaching the target. $\vec{X}$ signifies the position vector of the grey wolf besides $\vec{X}_p$ designates the position vector of the target.

The coefficient vectors $\vec{B}$ and $\vec{O}$ expressed as given in the equations respectively in (28) and (29):

$$\vec{B} = 2 * \vec{l} * \vec{r}_1 - \vec{l} \tag{28}$$

$$\vec{O} = 2 * \vec{r}_2 \tag{29}$$

While $\vec{l}$ shrinks proportionally from 2 to 0 at the time of iterations $\vec{r}$ and 1 and 2 will be arbitrary vectors within the range [0, 1].

3) Hunting: Subsequently, with the surrounding of the target, they are focused on hunting the target. The process of hunting normally is directed with the help of α, β & ϒ categories wolves. Out of these, 'a' delivers the finest candidate answer. Mathematically, the hunting performance of the mentioned animals will be expressed as given from (30) to (36).

$$\vec{E}_\alpha = [\vec{O}_1 \vec{X}_\alpha - \vec{X}_i] \tag{30}$$

$$\vec{E}_\beta = [\vec{O}_2 \vec{X}_\beta - \vec{X}_i] \tag{31}$$

$$\vec{E}_\Upsilon = [\vec{O}_3 \vec{X}_\Upsilon - \vec{X}_i] \tag{32}$$

$$\vec{X}_1 = \vec{X}_\alpha(i) - \vec{B}_1.\vec{E}_\alpha \tag{33}$$

$$\vec{X}_2 = \vec{X}_\beta(i) - \vec{B}_2.\vec{E}_\beta \tag{34}$$

$$\vec{X}_3 = \vec{X}_\Upsilon(i) - \vec{B}_3.\vec{E}_\Upsilon \tag{35}$$

$$\vec{X}(i+1) = \frac{(X_1 + X_2 + X_3)}{3} \tag{36}$$

4) Attacking prey: After the accomplishment of hunting, they try to ambush the target. Permission of the search agents by the GWO techniques i.e., wolves try to update their locations for attacking the prey and are provided as per the position of α, β and γ class of wolves. It supports generating a dependable solution. For explaining the model for reaching the target, two vectors $\vec{a}$ and $\vec{A}$ are taken into consideration. Therefore, $\vec{a}$ proportional shrinkages from 2 to 0 while the iteration upsurges in addition to the oscillations of $\vec{A}$ and also diminished by the $\vec{a}$. But $\vec{A}$ is an arbitrary value between [-a, a].While $\vec{A}$ takes any arbitrary value within the range [-1, 1], the subsequent location of animal might indicate from its present location to the target location.

A. Chaotic Grey Wolf Optimization Algorithm

Even though GWO has a decent proportion of convergence mechanisms, it is not able to accomplish the global optimization which impacts the convergence mechanism under all circumstances. CGWO Algorithm is designed by efficiently combining the non-linear chaos theorem in the GWO technique to diminish the convergence impact and enhance the effectiveness. Chaos is defined as a deterministic and arbitrary technique established in a non-linear, dynamic framework that is periodic, non-converging and constrained. Regularly, numerous combinatorial optimization problems are encountered, nevertheless, one should be ready to determine the solution for the related issue. This can include proper allocation of resources including time, strategizing the product delivery, devising the proper circuit, and computer wiring. The significant challenge in technology and engineering is the formulation of competent techniques for designing the solutions to these combinatorial problems.

Chaos is explained as the arbitrariness of an active framework and a chaotic system may be measured as the foundation for arbitrariness. Repeated chaotic neural networks are efficient for determining combinatorial optimization problems. Nevertheless, the technique cannot be enforced to very huge circumstances because it requires a large quantity of memory to build the design of the neural network. Because of the firing pattern of Chaotic Neural Network encoding of the solution, it is so much complicated to achieve the possible solutions. When the firing pattern of the neural network pleases the conditions then the solution is produced in that circumstance. For determining solutions to the mentioned critical restrictions. Chaotic Neurons inspire heuristic algorithms [33].

Chaotic Dynamics is meticulously utilized in the employment of local exploration techniques. The fundamental component of the chaotic neuron is projected by Kitajima *et al*. [34]. Implementation of the local exploration algorithm is encoded by the firing of the chaotic neuron. If the chaotic neuron fires, the respective local search algorithm is implemented. Once the neuron starts firing, then the subsequent firing of the neuron will occur only after a finite duration. The firing process will be inhibited for a certain duration with the help of the assertiveness of chaotic neurons. It can be thus inferred that the recurrent firing of the neuron and regular accomplishment of the local search algorithm is circumscribed. Hence, chaotic exploration might efficiently avoid local minima. At that point, it stresses the fact by which impetuousness employed with chaotic neuron model results in similar or sometimes bigger resolving capacity than tabu search that contains a similar approach of exploring solutions as the chaotic exploration. Utilizing the aforementioned concept, chaotic search approaches are projected to determine the solution closer to optimality or estimated solutions for combinatorial optimization problems. Several chaotic maps containing diverse numerical expressions are utilized to combine the theory of chaos in optimization techniques.

Chaotic maps were extensively utilized along with the optimization area for the preceding ten years because of its dynamic nature that aid the optimization techniques in investigating the exploration space more vigorously and globally. A broader variety of Chaotic maps were formulated by engineers, investigators and specialists in the field of statistics in agreement with several human protectorates presently obtainable in the area of optimization [35]. Out of the accessible chaotic maps, a major portion was frequently enforced in optimization techniques to utilize in real-time circumstances. Ten appropriate single-dimensional chaotic maps utilized in this research work as gathered and analyzed from the available literature to confront CGWO is listed in Table II [36].

Any arbitrary number within the specified range of [0,1] might be selected as a starting value in those chaotic maps. However, it must be compulsorily observed that the starting value is creating pronounced effects over the oscillation pattern of certain maps. A diverse group of chaotic maps with the starting value as 0.7 is picked for utilization for all parameters [37]. The convergence mechanism of the GWO technique is getting affected by utilizing Chaotic maps completely along with the optimization as the maps influence the possible area of the GWO technique using Chaos non-linearity. Initially, the maps are anticipated to perform on the GWO only for a brief duration, but the effect prevailed stochastic for a longer duration. A brief algorithm explaining the projected CGWO algorithm for determining the solutions of optimization problems is established in Fig. 3.

For adjustment of key parameter 'a' which is critical in determining the convergence speed and improving the Location of Grey Wolves, the functionality of ten diverse chaotic maps was utilized and examined. Two-stage OP-AMP is formulated for 180nm technology as provided in Table I as per the subsequent requirements.

TABLE I. DESIGN SPECIFICATIONS

Parameters	Values	Parameters	Values
Open Loop Gain	≥ 100V/V (40 dB)	Trans-conductance of PMOS K'_P	$(\frac{\mu_p C_{ox}}{2})$ = 35.6 µA /V^2
Slew Rate	≥ 10 V / µs	Threshold Voltage of NMOS V_{tn}	0.35 V
f_{-3dB}	≥ 5MHZ	Threshold Voltage of PMOS V_{tp}	-0.39 V
Load Capacitance	≥ 10 pf	Phase Margin	≥60 Degree
Positive Supply Voltage V_{DD}	2.5 V	CMRR	≥60 dB
Negative Supply Voltage V_{SS}	-2.5 V	PSRR	≥60 dB
Power Dissipation	≤ 2000 µ watt	Channel length modulation parameter for NMOS λn	0.09 / V
Common mode Input range	-1.5 V≤ ICMR ≤ 2V	Channel length modulation parameter for PMOS λn	0.1 / V
Aspect Ratio	$2 \leq \frac{W_i}{L_i} \leq 100$	Trans-conductance of NMOS $K'_{N'}$	$(\frac{\mu_n C_{ox}}{2})$ = 177.2 µA /V^2

The Optimization Technique with Projected CGWO Strategy is provided in Fig. 2. Stochastic initialization of the population of grey wolves is carried out in this initial phase. In addition to the beginning of the process and selection, its initial chaotic number and a variable chaotic function that is required to be mapped with the GWO technique is also picked [35]. Consecutively, the parameters of the CGWO algorithm consisted of performing the exploration, – exploitation techniques, namely, a, A and C that will be like comparison with GWO. Within the exploration space, the fitness of all grey wolves is estimated utilizing several typical yardstick functions and are addressed by their fitness. After arrangement and organizing the first wolf is presumed as α wolf and consequently, second and third wolves are presumed to be β and γ wolf correspondingly. As a result, the fittest wolf shall be preserved by improving its location using Equation (36) and might obtain the location of α wolf as the best solution. As the progression of iterations using Equations (28) and Equation (29), the characteristic values get improved. Fitness of the Wolf is taken into consideration as the healthier solution determined by the CGWO technique after reaching the final iteration.

B. CGWO for Constrained Benchmark Functions

Two functions that are listed as Motivation Function and non-conformity of Constrains functions are utilized in the explanation of all the optimization problems with the set of conditions [39]. Objective function will be explained as the function that is having the foremost intention for determining the optimal solution say `x' in the particular exploration space. It is expressed in (37).

$$\text{Minimize } f(x),\ x = (x_1, x_2, x_3, \ldots\ldots x_n) \ \varepsilon\ R^n \qquad (37)$$

where n is the number of dimensions that a solution is comprised of. X ϵ F ϵ S in which F is the practicable region in exploration space S that explains an n-dimensional rectangle R [38].The mentioned rectangle R has domain size within the range of lower limit (ll) and upper bound (ul) as signified in (38).

$$ll(i) \le x(i) \le ul(i),\ 1 \le i \le n \qquad (38)$$

and the number of conditions to be satisfied are said m (m> 0) will be explained in the F space in Equation. (39).

$$g_j(x) \le 0 \text{ for } j = 1,2,3\ldots q$$

$$h_j(x) = 0 \text{ for } j = q+1, \ldots\ldots m \qquad (39)$$

Here $g_j(x)$ and $h_j(x)$ are termed as in-equivalence and equivalence conditions. If any solution says `x' pleases the condition g_k or h_k in F space, then g_k is measured to be a dynamic condition at x.

V. Experimental Results

A. CGWO based Circuit Design

To achieve the best circuit sizing for two-phase CMOS Operational Amplifiers CGWO technique is applied. The optimal sizes of the MOS transistors along with Load Capacitance and Compensation Capacitance by minimizing the primary objectives that are power dissipation and area is performed by the proposed CGWO technique. Along with the operation proposed algorithm so that it satisfies specified formulation characteristics and conditions for the design. By manually identifying the power supply values and the characteristic values for the selected technology must be performed during the optimization procedure. The parameter values for the selected technology, values for the power supply and the boundaries of design parameters and specifications are provided as inputs for the Optimization Algorithm. Optimally Corrected solution for design parameters ((*Wi/Li*), C_C, P_{diss} in addition to the specifications for formulation (*SR*, A_V, $f\text{-}3_{db}$, V_{IC} (*max*), V_{IC} (*min*), C_L *OFFSET*), where i = 1, 2, ..., 8 is provided by the projected technique for two-step Op-Amp circuit using CMOS transistor chosen in the proposed papers. Schematic of two stage OP-AMP is shown in Fig. 4 and simulated using Mentor graphic technology and this technique is utilized invalidating the answers provided by the recommended technique.

Parameter values specified for the design proposal and the selected technology (180 nm) are presented in Table III. Simulations are carried out using the system with CPU Intel core i7 that contains 4 GB RAM and MATLAB. For the proposed CGWO algorithm, the total quantity of search agents selected is 50 and the dimension chosen is 10 i.e. the design variables picked for the proposed circuits are 7. The highest number of iterations selected for the recommended technique is 100. Schematic and Gain of the proposed two stage operational amplifier versus frequency is shown in Fig. 4 and Fig. 5. Also, Power dissipation versus time also shown in Fig. 6. Table II contains various chaotic maps and their corresponding expressions which are used in CGWO.

TABLE II. LIST OF CHAOTIC MAPS AND THEIR EXPRESSIONS UTILIZED IN CGWO

S.No	**Name of the Maps**	**The expression for the map**
1	Bernoulli map	$x_{k+1} = \frac{x_k}{1-a} \quad 0 \leq x_k \leq a$ $= \frac{x_k-(1-a)}{a} \quad 1-a \leq x_k \leq 1$
2	Logistic map	$x_{k+1} = a.\, x_k (1- x_k)$
3	Chebyshev map	$x_{k+1} = \cos(a \cos^{-1} x_k)$
4	Circle map	$x_{k+1} = x_k + b - \frac{a}{2\pi}\sin(2\pi x_k) \bmod (1)$
5	Cubic map	$x_{k+1} = p\,(1 - x_k^2) \quad x_k\ \varepsilon\ (0,1)$
6	Iterative chaotic map with infinite collapses (ICMIC) map	$x_{k+1} = abs\,(\sin(\frac{a}{x_k})) \quad a\ \varepsilon\ (0,1)$
7	Piecewise map	$x_{k+1} = \frac{x_k}{a} \quad 0 \leq x_k \leq a$ $= \frac{x_k-a}{0.5-a} \quad a \leq x_k \leq 0.5$ $= \frac{1-a-x_k}{0.5-a} \quad 0.5 \leq x_k \leq 1-a$ $= \frac{1-x_k}{a} \quad 1-a \leq x_k \leq 1$
8	Singer map	$x_{k+1} = a\,(7.86x_k - 23.31x_k^2 + 28.75\, x_k^3 - 13.302875\, x_k^4)$
9	Sinusoidal map	$x_{k+1} = a\, x_k^2 \sin(\pi x_k)$
10	Tent map	$x_{k+1} = \frac{x_k}{0.7} \quad x_k < 0.7$ $= \frac{10}{3}(1-x_k) \quad x_k \geq 0.7$

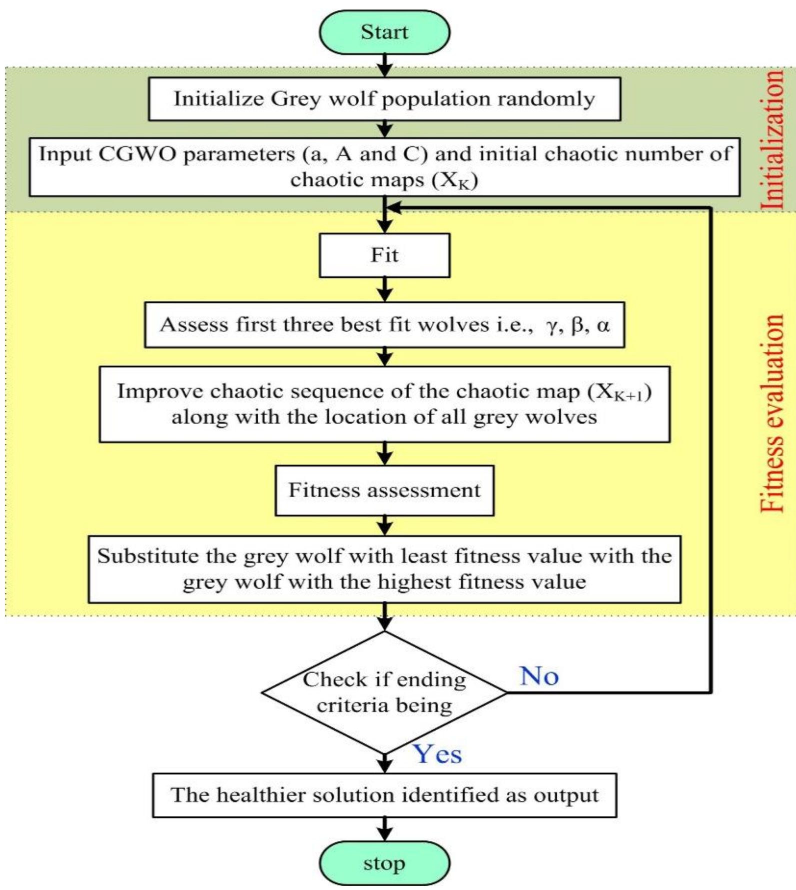

Fig 2. Flow Chart of Optimization Using CGWO.

Initialize the generation counter t and arbitrarily start the population X_i of grey wolves X_i were (i =1, 2…. n)
Initialize the value of the Chaotic map x_o arbitrarily
Initialize parameters a, A and C
Determine the fitness of every wolf
X_α =The the best wolf
X_β =The second-best wolf
X_δ =The third-best wolf
While (t < Max_ iterations)
Organize the population of Grey Wolves following their fitness
Improve the chaotic number utilizing chaotic map equation
For every search agent
Improve the location of Current wolf utilizing equation 36
End for
Improve the parameters a, A, C
Determine the fitness of all wolves
Improve X_α, $X_{\beta,\text{ and}}$ X_δ
Modify the worst fit wolf with the best fit wolf
t=t+1
End while
Return X_α

Fig 3. Algorithm of Proposed CGWO.

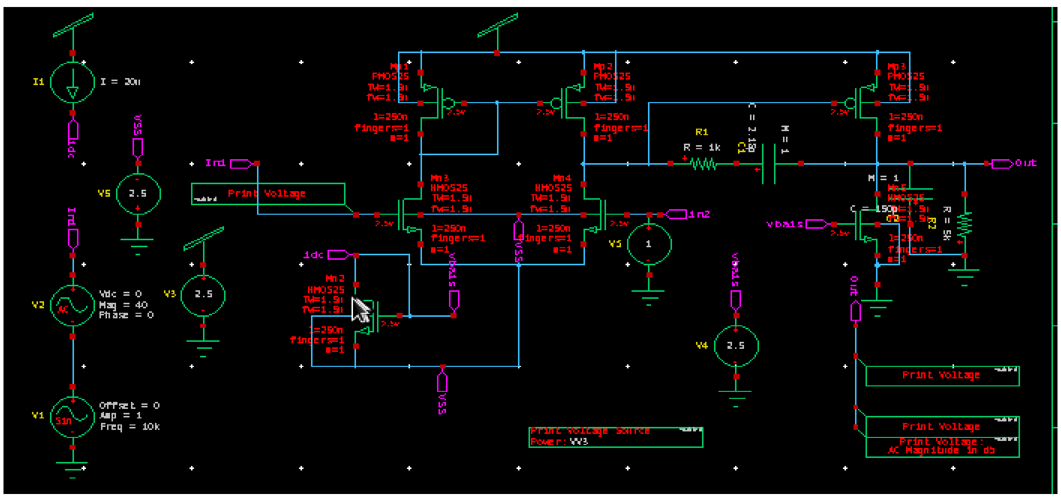

Fig 4. Schematic of the Proposed Two Stage CMOS Operational Amplifier.

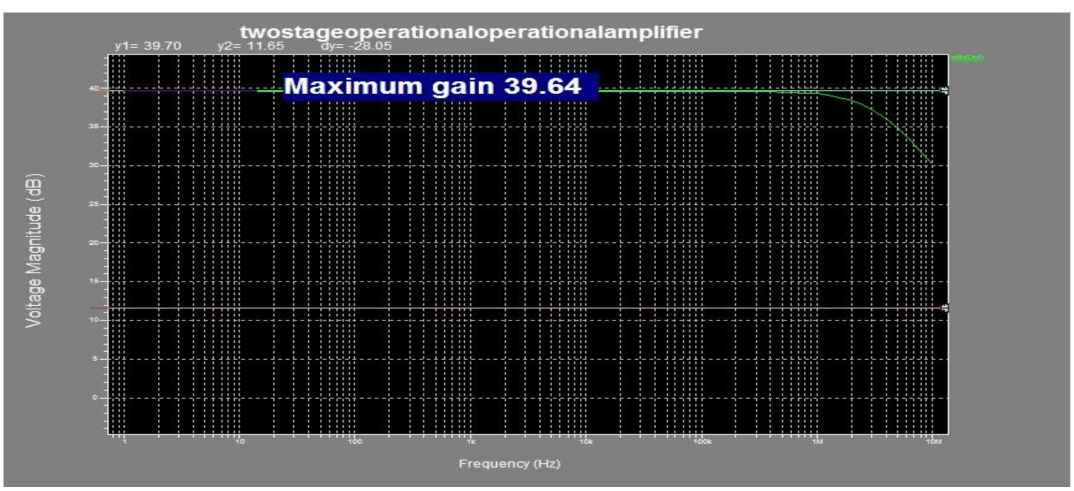

Fig 5. Gain of the Proposed Two Stage CMOS Operational Amplifier.

Fig 6. Power Dissipation of the Proposed Two Stage CMOS Operational Amplifier (72uw).

Table III contains Technology parameters, inputs and lengths of MOS transistors and Table IV. contains the values for the parameters attained for diverse techniques applied for the proposed circuit. Table V. Presents the values for the specifications attained by the diverse techniques employed for the proposed circuit.

TABLE III. TECHNOLOGY PARAMETERS, INPUTS, AND LENGTH OF MOS TRANSISTORS

S.No	Specification	Values used
1	V_{DD}(V)	2.5
2	V_{SS} (V)	-2.5
3	V_{tP}(V)	-0.39
4	Vtn(V)	0.35
5	$K'_{N'}$ (μA/V^2)	177.2
6	K'_P(μA/V^2)	35.6
7	Length (μm)	0.18

TABLE IV. VALUES FOR THE PARAMETERS ATTAINED FOR DIVERSE TECHNIQUES FOR THE PROPOSED CIRCUIT

Design Parameters	CGWO	GA	DE
I_{BIAS}(μA)	22.2	34.5	42
C_c	2.18 pf	2.43 pf	2.47 pf
W_1/L_1	8=1.44/0.18	2/0.18	4/0.18
W_2/L_2	8=1.44/0.18	2/0.18	4/0.18
W_3/L_3	4=0.72/.18	4/018	4/0.18
W_4/L_4	4=0.72/0.18	4/0.18	4/0.18
W_5/L_5	1=0.4/0.4	2/0.18	4/0.18
W_6/L_6	40=7.20/0.18	22.64/0.18	24.86/0.18
W_7/L_7	8=1.44/0.18	8/0.18	8.2/0.18

The CMRR can be computed as $\text{CMRR} = 20\,\text{LOG}_{10}\frac{A_{v\,DIFF}}{A_{v\,COMM}}$

The PSRR can be computed as $\text{PSRR} = 20\,\text{LOG}_{10}\frac{A_{v\,DIFF}}{A_{v\,PS}}$

TABLE V. VALUES FOR THE SPECIFICATIONS ATTAINED BY THE DIVERSE TECHNIQUES FOR THE PROPOSED CIRCUIT

Design Criteria	Specifications	CGWO	GA	DE
Slew Rate (V/ µs	≥ 10 V / µs	20	15	10
Load Capacitance C_L(pf)	≥ 10 pf	12	9	7
Gain in dB	40 dB	39.64	36.48	32.42
Unity Gain Bandwidth MHz	≥ 5 MHZ	18.43	16.54	12.14
$VI_{c\,(min)}$	≥ -1.5v	-0.01	-0.2	-1.2
$VI_{c\,(max)}$	≤ 2V	1.10	1.01	1.05
Power Dissipation P_{diss} (µw)	≤ 2000 µ watt	72	117	147.2
Total Area	≤300 μm^2	71.26	94.7	107.845
Phase Margin in Degree	≥60 Degree	58.6	48.4	42.7
CMRR	≥60 dB	134.6	133.7	132.7
PSRR	≥60 dB	180	179.1	178.2

VI. CONCLUSION

The motivation of this paper is to optimize the power dissipation in the design of a circuit with compact size and low power operational amplifier**.** For the design of two-step CMOS-OPAMP, a thoroughly explained strategy is presented in the paper. It is observed that the power dissipation accomplished with the CGWO technique performed superior to the genetic algorithm and differential evolution also attained the best convergence rate and duration complexity by analyzing the results with the above-mentioned algorithms. The designed circuit can offer a reasonable gain for open-loop configurations. On the other hand, the issue in the circumstance is the steadiness that might be diminished by utilizing the compensation procedures. The circuit selected employs the Miller Compensation methodology, in such a way that modest frequency compensation practice utilizes the Miller impact by joining a compensation capacitor in parallel to the high-gain phase. It is clearly explained from the achieved results that, utilizing CGWO as an optimization technique can minimize the current, power consumption and area as well.

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BERT+vnKG: Using Deep Learning and Knowledge Graph to Improve Vietnamese Question Answering System

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***Abstract*—A question answering (QA) system based on natural language processing and deep learning is a prominent area and is being researched widely. The Long Short-Term Memory (LSTM) model that is a variety of Recurrent Neural Network (RNN) used to be popular in machine translation, and question answering system. However, that model still has certainly limited capabilities, so a new model named Bidirectional Encoder Representation from Transformer (BERT) emerged to solve these restrictions. BERT has more advanced features than LSTM and shows state-of-the-art results in many tasks, especially in multilingual question answering system over the past few years. Nevertheless, we tried applying multilingual BERT model for a Vietnamese QA system and found that BERT model still has certainly limitation in term of time and precision to return a Vietnamese answer. The purpose of this study is to propose a method that solved above restriction of multilingual BERT and applied for question answering system about tourism in Vietnam. Our method combined BERT and knowledge graph to enhance accurately and find quickly for an answer. We experimented our crafted QA data about Vietnam tourism on three models such as LSTM, BERT fine-tuned multilingual for QA (BERT for QA), and BERT+vnKG. As a result, our model outperformed two previous models in terms of accuracy and time. This research can also be applied to other fields such as finance, e-commerce, and so on.**

Keywords*—Bidirectional Encoder Representation from Transformer (BERT); knowledge graph; Question Answering (QA); Long Short-Term Memory (LSTM); deep learning; Vietnamese tourism; natural language processing

I. Introduction

Question answering system using deep learning is a challenging field and has received a lot of attention in recent years. Question answering system is also highly applied in practice. Answering questions automatically helps investors make market price decisions, users can order products anytime, visitors can ask about tourism places, etc. The question answering system accepts a natural language input question and the returned result is a natural language answer in a specific field. Many models have been applied for this system such as LSTM, knowledge graph and BERT, which are surveyed in this section. Besides that, we also used combined model to improve the efficiency of the Vietnamese question answering system that can be applied in Vietnam tourism.

Question answering system using the LSTM model has been extensively studied because LSTM can predict next word due to permanently store the status of words based on context of previous sentences [1] [2]. Di Wang et al. proposed a method that combined Bidirectional Long-Short Term Memory (BiLSTM) and keywords matching to choose an answer sentence without using parsing syntax or any additional resources [3]. This model loaded words from questions and answers and returned their appropriate score for every answer. Firstly, the method put a tag <S> at the end of every question to discriminate answers. Each word of an input question was encoded into vector by using word2vec. Afterwards, BiLSTM read both of them according to two directions that kept previous and future context of words in questions and answers. These contexts were stored in cell memory vectors combined to generate hidden vectors. The final hidden vectors were labeled to determine whether the correct answer for input question. In addition, their method associated with keywords matching to indicate the correct answer and to avoid proper nouns not existed in vocabulary of word embedding.

G. Rohit used LSTM and memory network to build question answering system for professional fields [4]. For the LSTM model, the authors converted all exchanged content in a dataset by using word2vec from Google. The question was then added to each text that contained the answer as input for LSTM. Each word in the text was predicted according to the difference between the question and the text. This discrepancy was sent back to LSTM to reprocess until the prediction matched the question. For memory network, the authors' system had four components: (1) input featured map converted questions into vectors, (2) generalization compressed and generalized the old memory for the next step, (3) output featured map generated a new output from the new input and the current memory state, (4) the response converted the result from (3) into an appropriate readable format.

Besides LSTM model, knowledge graph is also applied to build question answering system instead of natural language understanding, recommender systems [5] [6] [7] [8]. Ben Hix et al. established the KNOWBOT system as a Q&A system about science and collected relationships between concepts in each question [9]. They collected 107 scientific questions from the 4th York New York Regents test, where each question had 4 answers that would be converted into question-answer pairs and labeled True for the correct answer and False for the wrong answer. KNOWBOT built graphs from dialog and utterance. To build utterance graphs, the system converted a user's sentence into a fully conceptual relationship after removing stop words in the sentence. To construct a graph from a dialog, the system created edges taken from utterance and calculated score for the answers in relation set. This set included questions and supporting sentences obtained from text corpus that appeared in the dialog graph. From the above calculated score, the system easily found correct answers for questions.

Xiao Huang et al. presented knowledge embedding based on question answering to look up a triple likes (head, predicate, tail) of input question in knowledge graph embedding and found relevant facts as correct answers [10]. Their model included three stages: (1) from input question, the model took a question as input parameter and trained predicate learning model to obtain a vector representing predicate. Then, head entity learning model was also trained to get head entity representing vector of input question. (2) Head Entity Detection model was executed to filter appropriate candidate entities for declining searching space. (3) The model used a function to calculate a score for each candidate tail entity as an answer.

As mentioned above, LSTM model had some certain drawbacks, so BERT (Bidirectional Encoder Representations from Transformers) has emerged as a model that is more outstanding than LSTM. Jacob Devlin et al. invented BERT to improve drawbacks of previous models that processed according to one direction [11]. BERT uses a masked language model (LM) to randomly tag tokens with masks in the input sentence, then the model predicts appropriate vocabulary for the labels based on the context of the sentence. The masked language model allows bidirectional contextual training from left to right and vice versa. The model has two steps: pre-training and fine-tuning. For the pre-training step, BERT uses two Masked LM tasks and Next Sentence Predict. In the former task, Masked LM, the model randomly selects 15% of the tokens in the sentence. For each chosen *i-th* word, it will be replaced by [MASK] token, then BERT will predict the masked word in the original dictionary for that token with cross entropy loss function. In the latter task, Next Sentence Predict, the model is applied to understand the relationship between sentences using binary next sentence prediction task from any corpus. For example, model selects two sentences S_1 and S_2 to train, if S_2 appears 50% after S_1, it will be labeled IsNext; if S_2 is a random sentence in the corpus, it will be assigned NotNext. In the latter task, fine-tuning step, BERT will encode text before using the self-attention mechanism to predict words in sentences. BERT is also applied in the question answering system that takes input parameter that is a question-context pair and the output result will process token representing vector to give the answer [12]. BERT is designed to support many natural language processing tasks such as sentence classification, tokenization, emotional classification, and so on [13] [14] [15].

Aiting Liu et al. proposed BERT-CRF model to find entities in question and BERT-softmax to solve the entity disambiguation problem [16]. From there, they proposed the BB-KBQA (BERT-based Knowledge Base Question Answering) model that combined BERT with the knowledge base to represent the semantics of questions, entities and predicates. Their system consisted of three components such as entity linking, predicate linking and answer selection. The entity linking component used BERT-CRF to perform the question mentioned detection function to detect entities in question based on the input sequence and the final state vector passed to the CRF layer to predict labels for each token. In addition, entity linking also performed disambiguation entities based on the input sequence and final states. For each final state, the softmax function calculated probability of each labeled candidate entity which appeared in the sentence. The predicate mapping component was applied for predicate set in knowledge base that was obtained from the entities of the entity linking component. Candidate predicates were scored based on semantic similarity with the question. Finally, answer selection calculated total weight of the candidate entities with the candidate predicate and selected the highest-weight entity-predicate pair as the answer.

Dongfang Li et al. used BERT to select the answer [17]. They choose a pair of candidate answers and train them to choose the one that best fit the question. The input for the encoding step of the model was a triple (Q, POS, NEG) where Q was a given question, POS was a positive answer, and NEG was a negative answer. Then, they created two pairs of Q-POS and Q-NEG as fine-tuning input step of BERT to receive embedding [CLS]. The following layer was fully connected layer that calculated the score for each pair through the sigmoid function.

Most of the above models showed certain effectiveness for choosing answers to input questions. In particular, the BERT model has yielded state-of-the-art results, so it is applicable to many different languages [18] [19]. There also were some studies that combined BERT and knowledge graph. Liang Yao proposed BERT for knowledge graph completion (KG-BERT) that used BERT to classify triplets, predict links and predict relations in a knowledge graph [20]. Weijie Liu proposed a knowledge-enabled language representation (K-BERT) that used knowledge graph to embed into input sentence as a knowledge expert [21]. This aimed to clearly explain what head and tail entities of a triplet were. However, few studies have used BERT and knowledge graphs for question answering system. In this paper, we proposed a model named BERT+vnKG that was a combination of BERT and knowledge graph applied for the Vietnamese question answering system in tourism. Our model's results were more outstanding than two previous models such as BERT for multilingual QA and LSTM about accuracy and speed for an answer. Our contributions were as follows:

- Developing a knowledge graph in Vietnam tourism from Vietnamese non-textual materials. Knowledge graph used to narrow context space based on entities of input questions.
- Using BERT model to find answers accurately and fast for Vietnamese question answering system based on knowledge graph that was narrowed and converted into text.

- Test on hand-made Vietnamese question answering dataset and compare the effectiveness on LSTM, BERT, and BERT+vnKG

We presented components to establish a question answering system using BERT+vnKG in Section 2. In Section 3, we experimented the performance of LSTM, BERT and BERT+vnKG on Vietnam tourism crafted dataset. Finally, discussions and suggestions for future research of the system will be covered in Section 4.

II. Methodology

A. System Overview

This section presents an overview of the Q&A system for tourism in Vietnam and describes in detail each component. Fig. 1 shows an overview of the BERT+vnKG system that answered questions about visiting places in Vietnam. Firstly, the system accepts a natural language question. Secondly, the Extract Subject component is responsible for drawing out entities in the question. Then, these entities become the input parameter for the Subgraph component that is responsible for extracting a subgraph obtained from knowledge graph. This subgraph contains the extracted entities. If a subgraph exists, the subgraph is converted to context. Otherwise, the dataset become context. The contextual content and the question become the input for BERT to produce the final answer.

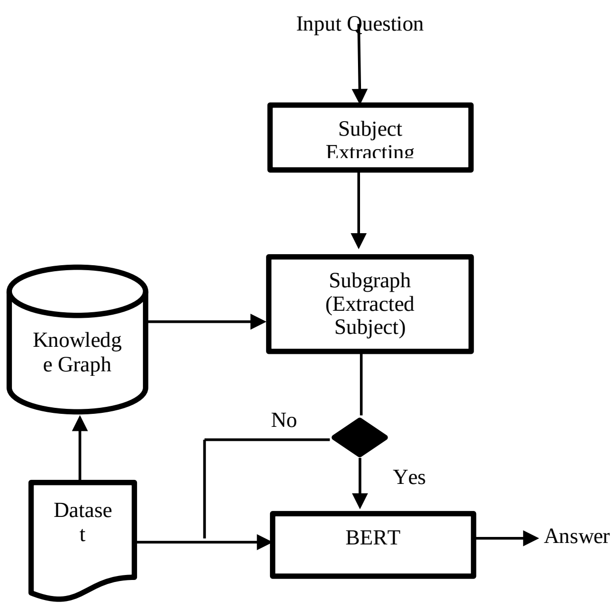

Fig 1. A Vietnamese Tourism Question Answering System using BERT.

B. Dataset

We create manual data by browsing contents of travel websites in Vietnam. We then generate a fact consisting of a pair of question and answer, which are separated by a label or symbol. For example, “Which bridge does Da Nang have? <BOA>Da Nang has Golden Bridge” is a fact, where <BOA> means “Begin of Answer” which is the label separating two sentences. We collect 300-paired sentences that included questions and answers about Vietnam tourist places and create more than 4600 relationships between entities from these sentence. This dataset is both to create the knowledge graph and to become context for BERT to find answers.

C. Knowledge Graph Module

A knowledge graph (KG) consists of a set of entities $E = \{e_1, e_2, ..., en\}$ that are nodes representing famous places and dishes in Vietnam and a set of relation R = {r1, r2, ..., rn} are predicates that link between two entities. For example, the sentence “Da Nang has Golden Bridge” is presented by knowledge graph as $Da\ Nang \xrightarrow{has} Gold\ Bridge$. Fig. 2 illustrated how we constructed the knowledge graph from the original corpus D.

From the travel data set, we use underthesea and VnCoreNLP library, which are open source natural language processing toolkits, to analyze sentences [22] [23]. For each sentence, we separate word tokens to draw a triple (e1, r, e2), where e1 and e2 are entities that appear in the sentence, r is a predicate of the sentence. From the triples, we create relationships and add them to the knowledge graph. This process is described in algorithms 1 and 2.

The pos_tag (s) function of the underthesea library is applied to assign label to each word in the sentence. A set E contains nouns or noun phrases in the sentence and a set V contains verbs in the sentence. For example, the sentence "Da Nang has Golden Bridge" was labeled as {("Da Nang", "Np"), ("has", "V"), ("Gold", "N"), ("Bridge" "," N "), E = {" Da Nang "," Gold Bridge "}, V = {" has "}. Finally, we create a relationship for the triple (e_i, v_i, e_{i+1}). Besides that, we also experienced another library named VnCoreNLP [23]. VnCoreNLP is also an open source that can be downloaded from [23]. The difference with underthesea is that VnCoreNLP has dependency parsing feature that can analyze relationships between parts of speech in a Vietnamese sentence. For example, a sentence “Da Nang has Gold Bridge” was parsed as [(“Da Nang”, “sub”, 2, 1), (“has”, “root”, 0, 2), (“Gold”, “nmod”, 4, 3), (“Bridge”, “dob”, 3, 4), (“.”, “punct”, 2, 5)]. From that, we have a triple t = (head, predicate, tail) as (“Da Nang”, “has”, “Gold Bridge”). But, we only create one-directional relationship for the triple because of semantic sentence. Consequence, the result of triple extracting using VnCoreNLP was more correct and semantic than the result using underthesea library. Therefore, we choose VnCoreNLP library as a major component of our system.

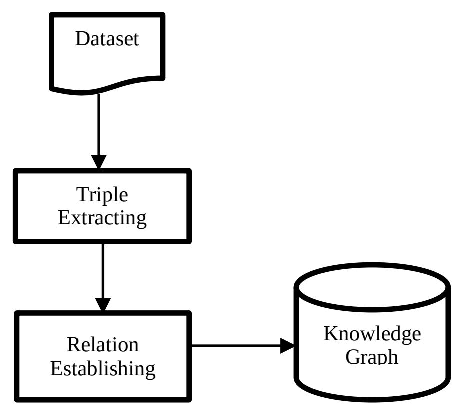

Fig 2. The Process Converted Each Sentence of Dataset into Knowledge Graph.

Algorithm 1 Pseudo code for extracting a triple of a sentence

Input A sentence s

Output A triple T = (e_1, r, e_2) represents for a sentence

```
Function ExtractTriple(s)
parse_sentence = Call vncorenlp.dep_parse(s) to execute dependency parsing for sentence s
for i ∈ parsen_tence do
    if i = "sub" then
        h ← h ∪ i
    Endif
Endfor
for i ∈ parse_sentence do
    if i = "root" then
        p ← p ∪ i
        if i ∉ {sub, punct, dob, pob} then
            p = p ∪ i
        Endif
    Endif
Endfor
for i ∈ parse_sentence do
    if i ∉ {sub, root, punct} then
        t = t ∪ i
    Endif
Endfor
T = ∅
if each t_i ∈ t then
    T ← T ∪ (h, p, t_i)
endif
Return T
End Function
```

Algorithm 2 creates a knowledge graph with more than 4600 triples describing the relationships between the two entities in the sentence. We save this graph to a text file for supporting BERT model to find the answers.

Algorithm 2 Pseudo code for building a knowledge graph

Input: Vietnamese tourism dataset D

Output: Knowledge graph G

```
Function BuildKnowledgeGraph(D)
G ← ∅
for d ∈ D do
    K ← ExtractTriple(d)
    for k ∈ K do
        G ← G ∪ k
    endfor
endfor
Return G
End Function
```

D. Subject Extracting Module

This component extracts places or dishes that were mentioned in the question. We continued using the natural language processing functions of VnCoreNLP libraries to extract entities in question. We run dependency parsing function on the question to obtain subjects and predicates. For example, the sentence "Where is King Garden" is analyzed as R={"is"}, E = {"King Garden"}. This process is showed in algorithm 3.

Algorithm 3 Pseudo code for extracting entities from a question

Input: A question q

Output: Entity set E = {e_1, e_2, …} of question q

```
Function ExtractEntityFromQuestion (q)
parse_sentence = Call vncorenlp.dep_parse(q) to run dependency parsing on question q
for i ∈ parse_sentence do
    if i = "sub" then
        E ← E ∪ i
    endif
endfor
for i ∈ parse_sentence do
    if i ∉ {sub, root, punct} then
        E ← E ∪ i
    endif
endfor
Return E
End Function
```

E. Subgraph for Extracted Subjects Module

This component extracts subgraphs for the entities taken from input question. For each entity, we search the knowledge graph created from the dataset to collect entities related to entities in question. For example, "King Garden located in Thanh Thuy district, Phu Tho province" is analyzed for entity E = {"King Garden", "Thanh Thuy district", "Phu Tho province"} and episode R = {"located in"}. With the question "Where is King Garden?" We have the subgraphs related to the entity "King Garden" as follows:

$$King\ Garden \xrightarrow{located\ in} Thanh\ Thuy\ district$$

$$King\ Garden \xrightarrow{located\ in} Phu\ Tho\ province$$

Fig. 3 describes the process that extracted subgraphs for each entity in the question. Firstly, we use Subject Extracting module to obtain entities. Then, we apply Subgraph for Extracted Subjects module associated with the knowledge graph to collect subgraph of each entity. In Fig. 4, we show an example to demonstrate that process.

Algorithm 4 Pseudo code for finding subgraphs of entities

Input: Knowledge graph G, entity set E_q in question q
Output: A set of subgraph SG for E_q

Function FindSubgraphForEntity (G, E_q)
  for $e_i \in E_q$ **do**
    for triple t = (h_m ,r, t_n) $\in G$ ***do***
      if $e_i \in t$ **then**
        $SG \leftarrow SG \cup t$
      endif
    endfor
  endfor
  Return SG
End Function

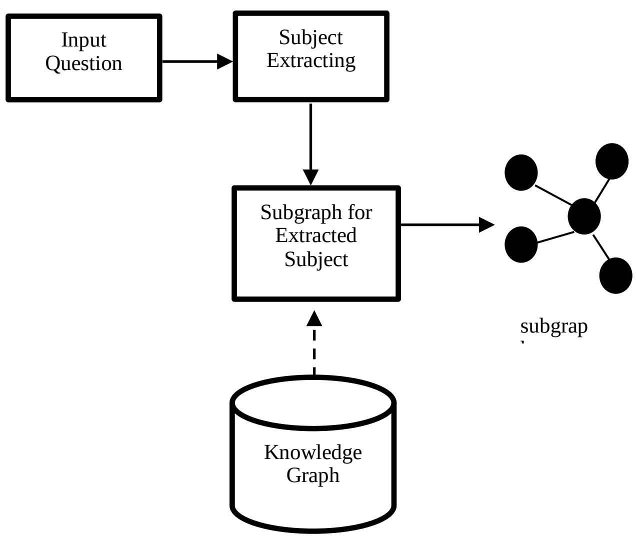

Fig 3. Illustration of Process that Extracted Subgraph from Knowledge Graph.

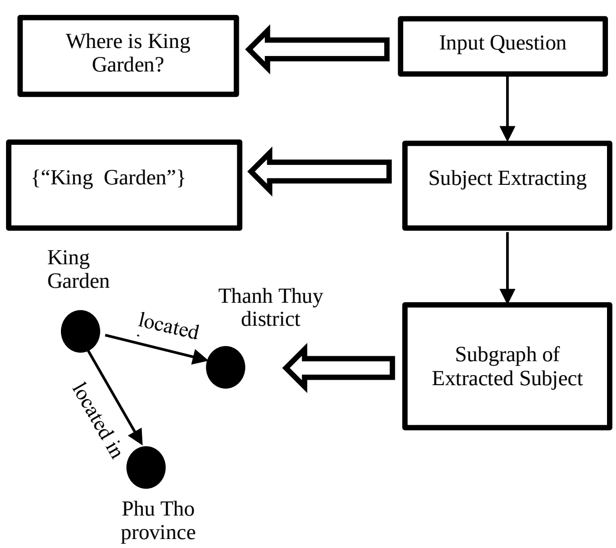

Fig 4. An Example about Extracting a Subgraph for Sentence "King Garden Located in Thanh Thuy District, Phu Tho Province"" was applied by Subgraph for Extracted Subject Module.

F. BERT Module

This component uses the BERT model to predict the answer. BERT is a masked language model with two main functions: pre-training and fine-tuning. BERT has many varieties such as BERT-Tiny, BERT-Mini, BERT-Small, BERT-Medium and BERT-Large. BERT-Base currently supports 104 languages including Vietnamese. BERT is used in many different applications, especially in the question answering system [24] [25] [26]. We use the fine-tuned BERT model for multilingual Q&A created by Manuel Romero because this model has dataset that is compatible with original dataset SQuAD v1.1 but also extends more eleven languages including Vietnamese language [27]. The input question, subgraph of entities relate to the question and dataset are fed as input parameters to BERT model to generate the answer. If the subgraph does not exist, BERT loads the question and original dataset to find the answer. In this case, time to respond an answer is very slow because BERT has to load entire content into memory. Otherwise, if the subgraph for entities existed, we converted the subgraph into textual context, then BERT used this context to find the answer. As a result, BERT determines the answer quickly because the value range for the candidate answers were narrowed.

Algorithm 5 Pseudo code for converting subgraph into context

Input: A subgraph *SG*
Output: Context c

Function SubgraphToContext (SG)
  for each triple $s \in SG$ **do**
    sentence ← $s.h \cup s.r \cup s.t$
    c ← c ∪ sentence
  endfor
  Return c
End Function

Algorithm 5 shows how to convert subgraphs to text as one of input parameters for BERT model. For each triple (h, r, t) in the subgraph, we join each component into sentences.

Algorithm 6 FindAnswerWithBERT (q, SG, D)

Input: Question q, subgraph *SG*, dataset *D*
Output: Answer a

Function FindAnswerWithBERT (q, SG, D)
  if $SG \neq \emptyset$ **then**
    c ← SubgraphToContext(SG)
    a ← BERT(q, c)
  else
    c ← D
    a ← BERT(q, c)
  endif
  Return a
End Function

Algorithm 6 shows how BERT predicts an answer. The best case happens when each entity in the question is able to derive subgraph from the knowledge graph to limit search space. The worst case occurs when entities in the question are not exist any subgraphs respectively, then BERT loads entire dataset to find the answer. Consequently, time to return an answer is very slow.

III. Experiment

A. Training and Testing Dataset

We collect over 300 questions and answers about famous places and dishes in Vietnam. Afterwards, we create three files as follows: facts.txt, questions.txt and answers.txt. The facts.txt file contains 300 question-answer pairs in the following format: *"question<BOS>answer"*. For example, we have a fact likes *"Where is King Garden? <BOS> King Garden is located in Thanh Thuy district, Phu Tho province"*. The *questions.txt* file contains only 300 questions that are separated from facts.txt file, the answers.txt file contains only 300 answers that are separated from facts.txt. A knowledgegraph.txt file contains 300 triples extracted from answers.txt to establish a knowledge graph. We use 80% of data in each file for training and 20% of data to evaluate the learning of models.

B. Metrics and Comparisions

We use the LSTM model with batch size = 32, latent dim = 256, epochs = 1000 parameters to experiment on facts.txt file. We then run BERT fine-tuned for QA model on the answers.txt file. Finally, we test our proposed model BERT+vnKG on answers.txt file. Three models are tested on computer with Intel Core i5-6200U CPU configuration 2.30 GHz 2.40 GHz, 16 GB RAM.

For LSTM model, each learning step loads all facts n = 300 pairs of questions and answers. This process repeats 1000 epochs, so the complexity is $O(n^2)$. For BERT multilingual for QA, for each question in the questions.txt file, the model loads entire answers n = 300 from the answers.txt file as a context to find answers, so the complexity is $O(n^2)$. We observe the run time of BERT for QA and calculate the following results: every 50 questions took three hours; the total time that BERT for QA answers 300 questions is T(n) = 300 * 3/50 = 18 hours. For BERT+vnKG model, because each question has subgraphs for its entities, so the domain for finding answers is narrowed. As a result, the complexity of this model is O(nlogn).

TABLE I. A Comparison about Time and Complexity among three Models as LSTM, BERT for multilingual QA and BERT+vnKG

Model	Dataset QA sentences	Approximate Time	Complexity
LSTM	300	4 hours	$O(n^2)$
BERT for multilingual QA	300	18 hours	$O(n^2)$
BERT+vnKG	**300**	**3 hours**	**O(nlogn)**

Table I shows the results that are experimented on 300 QA sentences and we observe the time that finishes answering prediction of three models. As a result, our model achieves more effectively than both LSTM and BERT for multilingual QA in term of time and complexity.

We use F1 to evaluate the accuracy of the three models [28]. Call TP as the sentences with real classes and the forecast is true positive, FP is the sentences with really positive class but the forecast is negative, TN is the sentences with real class but negative is forecast, positive and FN is Sentences with real class and forecast are negative. From here, we calculate the coefficient of F1 with the following formula

$$Precision = \frac{TP}{TP+FP} \tag{1}$$

$$Recall = \frac{TP}{TP+FN} \tag{2}$$

$$F1 = 2 \times \frac{Precision*Recall}{Precision+Recall} \tag{3}$$

Besides that, we also use Matthews Correlation Coefficient (MCC) to measure the quality classification of three models because it uses additional true negative part that F1 do not use [29]. The formula for calculating MCC is as follows:

$$MCC = \frac{TP*TN-FP*FN}{\sqrt{(TP+FP)(TP+FN)(TN+FP)(TN+FN)}} \tag{4}$$

Table II shows the predicted results of three models. We split our dataset into two parts such as 80% dataset for training and 20% dataset for testing. Besides that, we name correctly predicted sentences as positive and incorrectly predicted sentences as negative. These support to calculate F-measure and MCC score later.

TABLE II. A Comparison of Sentence Predicting among three Models: LSTM, BERT for Multilingual QA and BERT+vnKG

Model	Trained Data (80%) 240 QA sentences		Test Data (20%) 60 QA sentences	
	Positive	Negative	Positive	Negative
LSTM	202	38	52	8
BERT for multilingual QA	72	168	18	42
BERT+vnKG	**217**	**23**	**55**	**5**

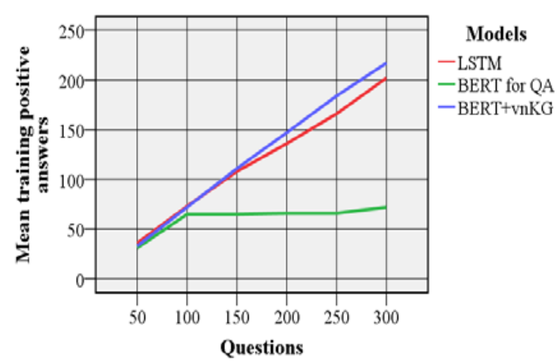

Fig 5. A Comparison of Three Models like LSTM, BERT for QA and BERT+vnKG about Predicting Positive Answers.

In Fig. 5, we evaluate the correct predicting based on means of answers that are classified into positive class. The values of vertical axis show positive answers' means of three models and the values of horizontal axis show questions that are tested. From results of Fig. 5, BERT+vnKG outperforms LSTM and BERT for multilingual QA.

Table III shows values of true positive (TP), false positive (FP), false negative (FN) that join above equations to calculate precise (P), recall (R) and F1 scores. Consequently, F-measure score of BERT+vnKG is higher than LSTM and BERT for multilingual QA.

TABLE III. A COMPARISON OF F1-SCORE ABOUT ACCURATE CLASSIFICATION AMONG THREE MODELS AS LSTM, BERT FOR MULTILINGUAL QA AND BERT+VNKG

Model	**TP**	**FP**	**FN**	**P**	**R**	**F1**
LSTM	202	38	8	0.84	0.96	0.90
BERT for multilingual QA	72	168	42	0.30	0.75	0.43
BERT+vnKG	**217**	**23**	**5**	**0.9**	**0.97**	**0.94**

In Fig. 6, we use F1 scores to compare classification of the models. The values in vertical axis show the F1 score's means of the models and the values in horizontal axis are the number of questions that are tested. According to this score, our proposed model originally predicts less correctly than LSTM at first 50 sentences, but the more sentences experiment, BERT+vnKG gives better result than LSTM and BERT for QA.

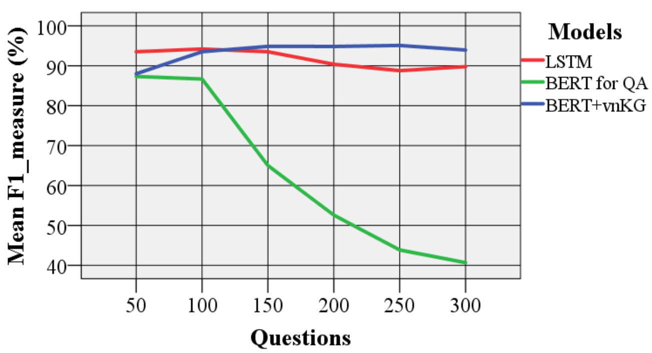

Fig 6. A Comparison of F1-Score about Binary Classification among LSTM, BERT for QA and BERT+vnKG.

TABLE IV. THE RESULT OF COMPARISONS ABOUT MCC SCORES FOR MEASURING THE QUALITY OF QUESTION ANSWERING CLASSIFICATIONS BASED ON THREE MODELS LIKE LSTM, BERT FOR MULTILINGUAL QA AND BERT+VNKG

Model	**TP**	**FP**	**FN**	**TN**	**MCC**
LSTM	202	38	8	46	0.59
BERT for multilingual QA	72	168	23	210	0.25
BERT+vnKG	**217**	**23**	**5**	**28**	**0.63**

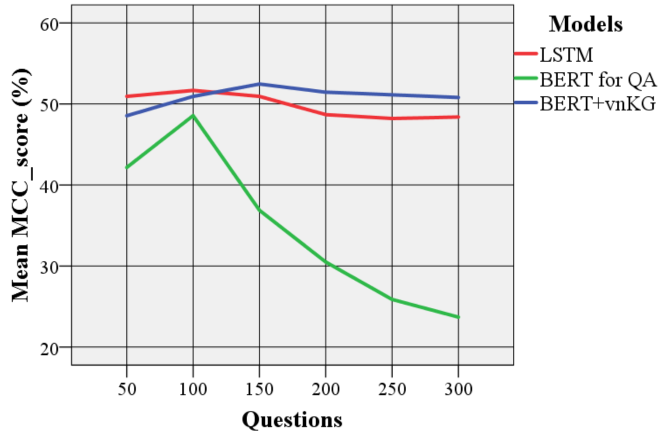

Fig 7. A Comparison of MCC Scores about Binary Classification among LSTM, BERT for QA and BERT+vnKG.

Table IV shows values of true positive (TP), false positive (FP), false negative (FN) and true negative (TN) that use to calculate MCC scores of three models. As a result, the MCC score of BERT+vnKG is higher than two remaining models.

In Fig. 7, we use MCC scores to evaluate correct classification of three models. This score is calculated from four variables such as True Positive, False Positive, False Negative and True Negative; meanwhile, F1-score only concentrate on first three variables. The values in vertical axis show the MCC score's means of the models and the values in horizontal axis are the number of questions that are experimented.

From the above tables, the coefficient F1=0.94 and MCC=0.63 show that our proposed model returns answers better than the other two models like LSTM and BERT.

IV. CONCLUSION

BERT model has brought about effectively state-of-the-art results in natural language processing, especially in machine reading comprehension. Moreover, BERT supports multiple languages including Vietnamese, so we have used this model to build a QA system about Vietnam tourism. However, using only BERT model does not return high accuracy for Vietnamese answers. Therefore, we have combined BERT and knowledge graph to improve the precision of Vietnamese question answering system. Using knowledge graph has limited search space for BERT to find answers. As a result, our system achieved both high accuracy and time improvement through experimenting on three models such as LSTM, BERT and BERT+vnKG with dataset which collected visiting places and special dishes in Vietnam.

V. FUTURE WORK

Although our suggested model outperformed, the system also had some limitations such as our model returned incomplete answers because BERT used attention mechanism that only output key phrases in an answer, the dataset is relatively small with 300 pairs of questions and answers that did not prove the true power of BERT+vnKG model, and the time to test the models was quite long due to evaluating on computer that had low resources. Future work will experiment on various datasets having a certain benchmark and large scale. Plus, we will evaluate our system by using rich-resource services such as GPUs or TPUs to improve the processing speed for big data.

ACKNOWLEDGMENT

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A New Strategy for the Morphological and Colorimetric Recognition of Erythrocytes for the Diagnosis of Forms of Anemia based on Microscopic Color Images of Blood Smears

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***Abstract*—The detection of red blood cells based on morphology and colorimetric appearance is very important in improving hematology diagnostics. There are automatons capable of detecting certain forms, but these have limitations with regard to the formal identification of red blood cells because they consider certain cells to be red blood cells when they are not and vice versa. Other automata have limitations in their operation because they do not cover a sufficient area of the blood smear. In spite of their performance, biologists have very often resorted to the manual analysis of blood smears under an optical microscope for a morphological and colorimetric study. In this paper, we present a new strategy for semi-automatic identification of red blood cells based on their isolation, their automatic color segmentation using Otsu's algorithm and their morphology. The algorithms of our method have been implemented in the programming environment of the scientific software MATLAB resulting in an artificial intelligence application. The application, once launched, allows the biologist to select a region of interest containing the erythrocyte to be characterized, then a set of attributes are computed extracted from this target red blood cell. These attributes include compactness, perimeter, area, morphology, white and red proportions of the erythrocyte, etc. The types of anemia treated in this work concern the iron-deficiency, sickle-cell or falciform, thalassemia, hemolytic, etc. forms. The results obtained are excellent because they highlight different forms of anemia contracted in a patient.**

Keywords*—Erythrocyte; anemia; iron-deficiency; falciform; thalassemia; hemolytic; recognition; morphology; color; segmentation; histogram; Otsu

I. Introduction

Blood is a complex connective tissue that is subject to constant renewal. It is made up of a set of elements suspended in a liquid. These various elements, which are cells each performs specific functions necessary for the maintenance of life [1]. We can essentially distinguish three categories of circulating cells of various shapes, sizes and colors:

- Red blood cells or erythrocytes come from bone marrow and are essentially made up of hemoglobin,
- White blood cells or leukocytes and
- Platelets or thrombocytes.

The specific role of red blood cells is to favor gas exchange between deep cells through the lungs. White blood cells defend the body against aggression by pathogens and toxins, while platelets favor blood clotting in the event of injury by forming a platelet clot instead of being lost [1]. Healthy red blood cells have regularly rounded shapes (circular shape) on a blood smear with a slightly clear central area. This area is due to the absence of a nucleus. Red blood cells are practically uniform in size, the red color of a healthy red blood cell occupies most of the cell. These characteristics are altered by the presence of microbes, by the insufficiency or lack of certain nutrients in the body. The deformation and alteration of the color of the red blood cells is regularly indicative of a pathology. So, the recognition of each of these forms will allow us to have appropriate information on the related disease. The analysis and manually recognition of blood cells (white and red blood cells) from blood smears is a slow, tedious and subjective task. In addition, it depends on the skills and experience of the technician and can often lead to repeatability [2, 3, 4] of the tests. Therefore, the implementation of an automatic and accurate diagnostic procedure is necessary. For this purpose, there are automatons capable of detecting certain forms of red blood cells, but these have limitations in terms of their formal identification as they sometimes consider in practice a cluster of red blood cells to be a single red blood cell or often a large cluster is not considered to be a red blood cell, as shown by Godon A et al. in 2012 through their work on errors in blood counts produced by automatons [5]. In the thesis work presented by GRIMON Noemie in 2019 on the evaluation of automated microscopes, he showed that despite the speed and performance of automated microscopes, they present insufficiencies on the reading surface of blood smears, and revealed that, despite everything, digital cyto-morphology is still dependent on the

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visual examination of biologists [6]. Although time saving is an important factor in medical diagnosis, the reliability of the results remains the major element in the establishment of an effective treatment protocol. With this in mind, we propose a new strategy for the morphological and colorimetric identification of erythrocytes for the diagnosis of forms of anemia based on microscopic color images of Blood Smear. Following this approach, many researchers have tried to automate the detection, recognition and classification of blood cells from microscopic blood smear images using an image processing approach to help hematologists diagnose many diseases quickly and accurately. R. Tomaria et al. 2014 applied the morphological parameter compactness and the seven HU moment characteristics for red blood cell detection. The authors also developed an algorithm based on artificial neural networks to assign each cell the corresponding class [7]. In 2017 H.A. Elsalamony, for an identification of the normal blood cells, sickle cell and elliptocyte cells proceeded by a signature of each form by extracting the different morphological parameters characterizing each of the forms [8]. M. M. Abdul Jamil et al in 2019 used a marker-controlled watershed segmentation method to solve the thorny problem of cell overlap to detect blood cells. But this method increases the complexity of the algorithm [9]. The detection of blood cells, namely red and white blood cells, was the subject of work by C. Di Ruberto et al. in 2019. In their work, the authors used an Edge Boxes approach for simple cell detection [10]. Although efficient, this method does not allow us to appreciate certain morphologies and colorimetric aspects of the cells which are the basis of the importance of our work.

This research paper is organized as follows: Section II allows us to review the work carried out in the literature, Section III will deal with the materials and methods, the results will be discussed in Section IV and finally we will conclude with a conclusion and perspectives in Section V.

II. Related Work

Manual analysis and recognition of blood cells (white blood cells and red blood cells) from blood smears is a slow, tedious and subjective task. It also depends on the skills and experience of the technician and the results of analyzes show repeatability [2, 3, 4]. Therefore, an automatic and precise mechanism is needed to deal with the above-mentioned problems.

Many researchers have tried to automate the detection, recognition and classification of blood cells from microscopic images of blood smears using an image processing approach to help hematologists diagnose many diseases in a meaningful way fast and precise.

Given the importance of the subject, several studies have proposed methods for the automatic recognition and classifications of blood cells based on shape descriptors extracted from them [11, 12, 13]. Chettaoui. C. et al [14,] used several descriptors to identify the sickle red blood cell as in the work of. In this article the authors tested the correctness of each descriptor, namely the descriptors of the extremities, of the circumscribed inscribed circle, of Fourier and of Fourier Mellin. After the test carried out on each one, they opted for the descriptor of the inscribed-circumscribed circle as being the most precise.

In [15], the authors identified certain anemic red blood cells based on the automatic processing of images acquired on blood smears taken. Initially, they used the gray world technique and the geometric mean filter to respectively reduce the backlighting of the different smears and the noise associated with the images during the acquisition. Secondly, the cells were segmented using the watershed segmentation technique controlled by marker. For a better identification the authors used the logistic regression classiffer with a high precision of the order of 86.87% compared to the standard classiffers. These classifiers can be grouped into three (3) categories: supervised classifiers (SVM, Bayes algorithms, K-NN, Neural networks, CNN, Multilayer Perceptron, decision tree, etc.) [1- 16], non-classifiers -supervised (K-means, C-means, Fischer) [17] and hybrid classifiers [17].

Recently, D. A. TYAS et al [18], combined 64 characteristics to identify nine forms of red blood cells. This combination is based on the extraction of three types of characteristics: morphological characteristics, color and texture. The extraction of the different characteristics was carried out using the gray level co-occurrence matrices for the texture characteristics, the use of the color moments for the different color parameters, the moment invariants and the geometric parameters were proposed by the authors for the extraction of morphological parameters. Following this first step, the authors proposed the machine learning algorithms, namely the multilayer perceptron (MLP) with learning methods by back propagation for the classification of red blood cells.

III. Materials and Methods

A. Materials used

This work to identify forms of anemia in patients required blood samples. These samples helped to the preparation of blood smears, i.e. five (05) smears per patient, two (02) of which are retained per patient after physical analysis. The smears were then digitized through our images acquisition system composed of a microscope brand MOTIC equipped with a 6V-220W halogen lamp for the illumination of the sample coupled with a colour CMOS camera brand Moticam2 with a spatial resolution of 2 Megapixels. The latter is connected to a computer through a USB 3.0 port for the acquisition of digital microscopic colour images.

B. Methods

A medical application requires a precision in the identification in the diagnosis in order to propose the most appropriate clinical treatment because human life is delicate. In view of recent work [7, 8, 9, 10], a purely automatic processing and analysis of digital images induces errors in the detection of red blood cells, their morphologies and others. Therefore, in order to have a precise diagnosis, we propose a semi-automatic approach which consists in choosing in a first step, regions of interest, each containing red blood cells to be isolated, processed and analysed in order to solve upstream problems such as overlapping red blood cells, open red blood cells, etc.

This work was carried out in collaboration with the Yamoussoukro Regional Hospital Centre (CHR) and the Yamoussoukro Blood Transfusion Centre (CTS). Blood samples were taken from target patients known to the services of the CHR and the CTS concerning patients suffering from certain forms of anaemia. These are the ferriprive, sickle-cell or falciform, thalassemic, hemolytic forms, etc.

The blood smears were performed on different samples taken from the target patients. For the acquisition of the microscopic colour images from the blood smears, an adequate configuration of our instrumentation presented in Fig. 1 in the previous section was necessary to obtain well-contrasting and sharp images.

The following sections present the digital image acquisition protocol and the proposed semi-automated diagnostic method for the identification of the forms of anaemia a patient suffers from.

It should be noted that the blood smear is an examination prepared on a thin, stained slide and its analysis allows a morphological and colorimetric study of blood cells, in this case red blood cells or erythrocytes [6, 19].

1) Image acquisition protocol: The acquisition of the different images required the appropriate configuration of the camera and the microscope. The resolution of the images is 1600 x 1200. The colour's gains in the different channels are as follows: Red at 2.04, Green at 1.2, Blue at 1.12 when the white balance is activated. This configuration of the camera associated with that of the microscope as well as the illumination of the samples allowed us to acquire a series of images. The acquisition process is triggered as soon as the operator has a blood smear of quality duly prepared according to the procedure recommended by the World Health Organization (WHO) [20]. The blood smear is placed on the microscope stage as soon as the acquisition software is launched and then several images are acquired by connecting the camera to the computer using at least the USB cable. The optical images thus obtained were obtained with the objective 100 times (100X), which is equivalent to a magnification (G) of 1000 (eyepiece: 10X and objective 100X, i.e. a G = 10 X 100), giving a clear and well-contrasting morphological and colorimetric characterization of the red blood cells.

This step led to a first contribution which is the implementation of a database of microscopic colour images of patients.

We present some image acquisition results illustrated in Fig. 1.

The image in Fig. 1(a) shows red blood cells of regularly rounded shapes and uniform colouring with a slightly light-coloured central area: these are the characteristics of normal-looking red blood cells. Meanwhile, the images in Fig. 1(b) shows pale red blood cells with a largely light central area and a red coloration located at the periphery forming a ring. These are diseased red blood cells characteristic of a specific form of anaemia. In addition, while the image in Fig. 1(c) shows elongated elliptical red blood cells.

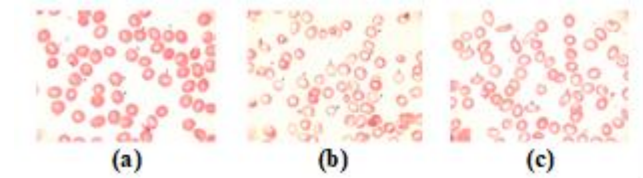


Fig. 1. Healthy Red Blood Cells, (b) Ring-Shaped Red Blood Cells (Annulocytes), (c) Elongated Red Blood Cells (Ovalocytes or Elliptocytes).

2) Methods for the identification of the proposed forms of anaemia.

a) Principle of the identification method: After the acquisition of microscopic color images of blood smears, we developed an application whose principle is illustrated in the flowchart in Fig. 3.

Its principle consists first of choosing an image of a patient's blood smear, then the application allows the selection of an area of interest containing the target red blood cell to be treated.

This area is segmented using a modified version of Otsu's segmentation algorithm combined with a search for related components in eight connexities under certain constraints to isolate the red blood cell followed by a partition of the red blood cell into two classes. The first class is the red area of the red blood cell and the second is the white area.

After the previous step of isolation and segmentation of the red blood cell, we calculate different morphological and colorimetric quantities of the red blood cell. These include, among others, the following: (i) the areas occupied by the red and white zone of the red blood cells, (ii) the total surface area of the red blood cell, (iii) the circumference of the red blood cell, (iv) the compactness, (v) the shape of the red blood cell, etc.

Finally, a test on the morphology and color of the red blood cell is carried out using the previously calculated quantities. From this step it is possible to detect a healthy or sick red blood cell. For a diseased red blood cell, it can be a question of identifying red blood cells such as sickle-shaped, circular (annulocytes), elliptical, pear-shaped, macrocytes, microcytes, hypochromic red blood cells, acanthocytes, etc. or combinations of shapes.

b) Semi-supervised selection of a region of interest and isolation of the target red blood cell: Following image acquisition, the proposed method requires the intervention of the operator, in this case the biologist. He selects through the developed application the region of interest containing the red blood cell to be identified. It is on this region that we apply Otsu's binary segmentation algorithm, combined with a search for related components under certain constraints that allows us to isolate the target red blood cell. The principle of related components is presented in the following sections. The binarization method by automatic thresholding makes it possible to separate the object from the background of the image, its principle is presented in the following section. An example of the isolation of the target hematite from the region of interest by our application is shown in Fig. 2.

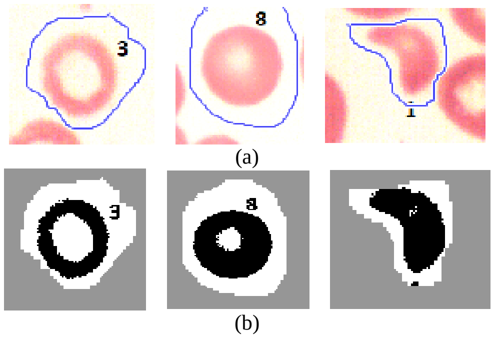


Fig. 2. (a) Region of Interest in Source Image, (b) Target Cell to be Isolated.

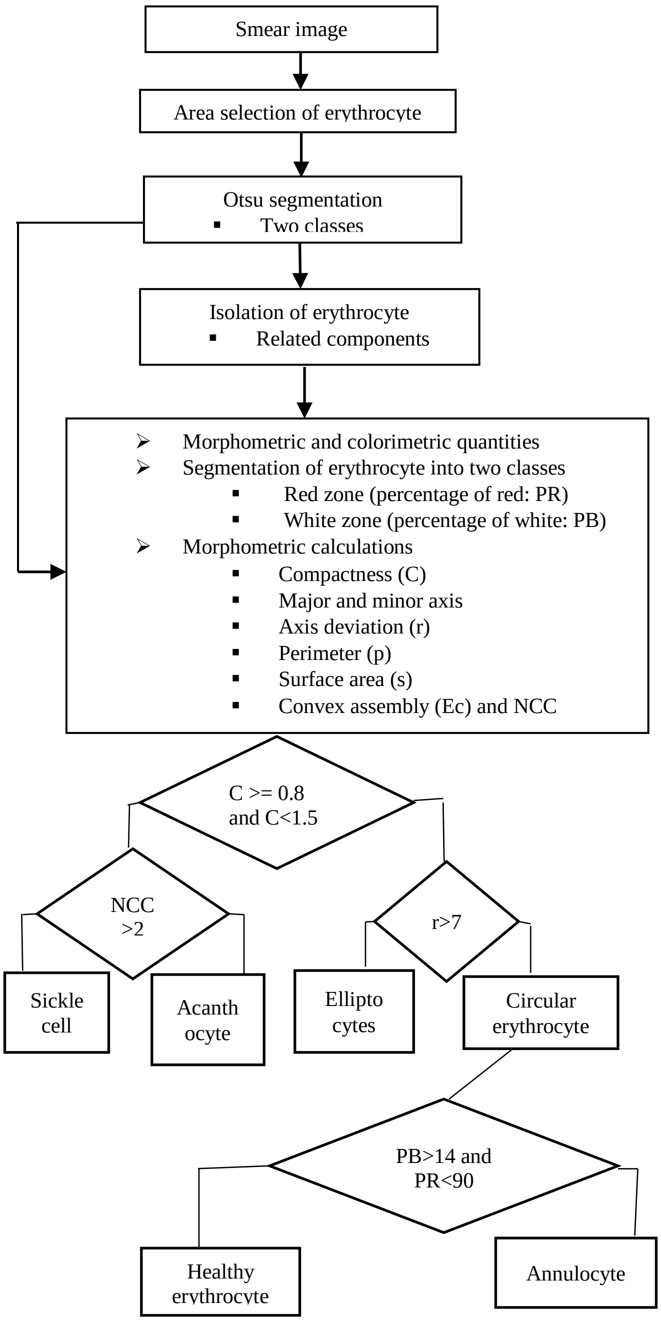


Fig. 3. Flowchart of the Method for the Identification of Erythrocytes Forms.

- Principle of the Otsu binary segmentation algorithm.

Let x be a variable describing the greyscale values of the image.

We wish to construct two (02) classes C1 and C2. Let P1(x) and P2(x) be the probabilities of classes C1 and C2.

Let σ1 and σ2 be the respective intra-class variances of classes C1 and C2.

Otsu's principle consists in choosing the threshold x minimizing the total intra-class variance [21, 22] that is minimiser σ_Total (x). Let:

$$\sigma_{Total}(x) = \mu_1(x)\sigma_1{}^2(x) + \mu_2(x)\sigma_2{}^2(x) \quad (1)$$

Or to maximize inter-class energy i.e. maximize σ inter (x). Let it be:

$$\sigma_{inter}(x) = \sigma^2 - \sigma^2_{Total}(x) = P_1(x)P_2(x)[\mu_1(x) - \mu_2(x)]^2 \quad (2)$$

The description of the algorithm is summarized in three steps as shown in the flowchart in Fig. 4.

- Related components and isolation of the red blood cell

After segmentation of the selected area by Otsu's method following automatic threshold search, it was possible to have a binarized image in which the region containing the red blood cell is the large black area as shown in Fig. 2(b), and thus an isolation of the target red blood cell was achieved. This isolation of red blood cells was made possible by the implementation of a related component search algorithm in eight (08) connects (see Table I for the related neighbours of the pixel (x, y)). Some examples of red blood cell isolation are shown in Fig. 5.

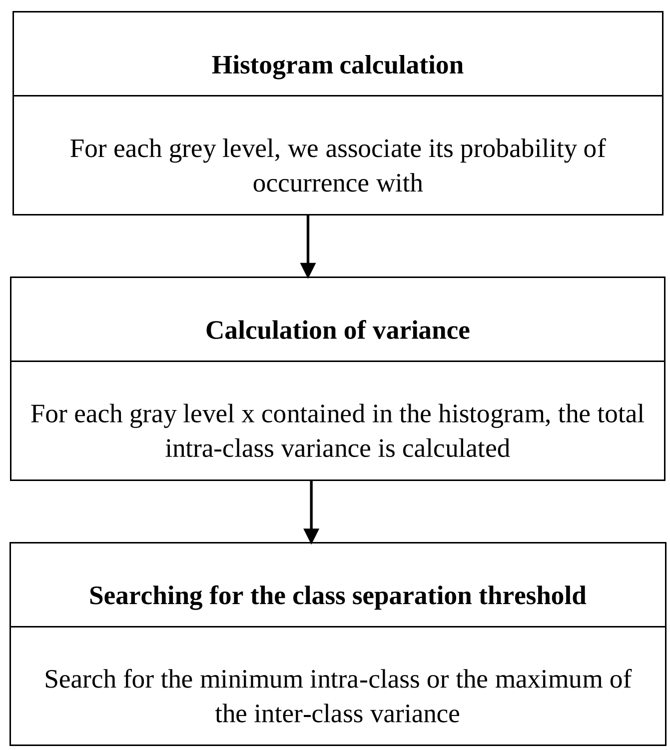
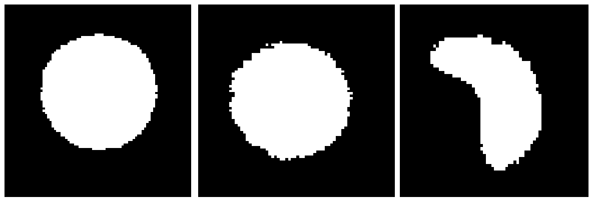


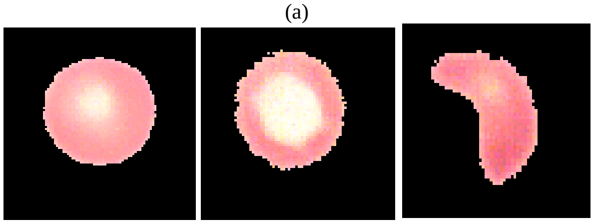
Fig. 4. Description of the Algorithm Steps.

TABLE I. TABLE SHOWING THE EIGHT CONNECTIONS OF A PIXEL (X, Y)

(x-1, y-1)	(x, y-1)	(x+1, y-1)
(x-1, y)	**(x, y)**	(x+1, y)
(x-1, y+1)	(x, y+1)	(x+1, y+1)



(a)



(b)

Fig. 5. (a) Erythrocyte Highlighted in the Segmentation Zone. (b) Erythrocyte Isolated from the Selection Area in the Real Image.

c) Estimation of morphometric and colorimetric magnitudes and implementation of a shape-testing algorithm for the red blood cells.

The calculation of the different morphometric and colorimetric quantities in a patient requires the complete isolation of the target red blood cells.

For the morphometric quantities, the estimation of parameters such as the area, perimeter, compactness of the red blood cells and others was discussed. The direct use of these morphometric quantities does not make it possible to directly predict the shape of a target red blood cell. Therefore, we have developed a clever algorithm to identify the shape of a hematite based on other quantities such as the major axis, minor axis, convex set, etc. These quantities are presented in the following sections.

As far as colorimetric quantities are concerned, we have estimated the average colour of each target hematite, the average colours of the red and white areas of the hematite as well as their proportions and others. Their calculations are also presented in a section below.

In sum, the calculation of the morphometric and colorimetric quantities was possible thanks to algorithms that we implemented in the MATLAB programming environment.

- Morphometric parameters

The pattern recognition system is undeniably based on different parameters. These parameters are measurements extracted from the object shapes [23]. Healthy red blood cells generally have circular shapes and a pinkish coloration on an MGG smear. All changes in each of these aspects are due to haematological pathologies such as anaemia. Anaemia is a disease related to red blood cells. It can be detected on a blood smear based on the staining and morphology of the red blood cells. The characterization of each form is made possible thanks to the morphometric parameters extracted from each healthy or diseased red blood cell.

The following Table II presents some parameters with their different formulas.

TABLE II. GROUPING THE EQUATIONS (EQUITATION 3 TO EQUATION 11) AND THEIR DESCRIPTION

Parameter	Equations	Descriptions
Area	$\boldsymbol{area} = \sum_x \sum_y f(x,y)$ **(3)**	Set of pixels covering the region that the cell represents.
Perimeter (P)	$\boldsymbol{P} = \sum_x \sum_y f(x,y)\ such\ as\ x, y \in F(\boldsymbol{R})$ (4)	The total number of pixels along the edge of the cell.
Compactness	$\boldsymbol{C} = \frac{4\pi.aire}{P^2}$ **(5)**	It is a morphological quantity that participates in the characterization of certain object shapes.
Major axis	**Majaxis**=max {dst (a, b) │a, b∈R} **(6)** **Majaxis**=max {dst (a, b) │a, b∈F(R)} **(7)**	These axes are obtained after the determination of the spatial barycentre of the isolated and binarized red blood cell.
Minor axis	**Minaxis**=min {dst (a, b) │a, b∈R} **(8)** **Minaxis**=min {dst (a, b) │a, b∈F(R)} **(9)**	The minor axis (Minaxis) is the smallest diameter of the cell passing through the barycentre.
Axis spacing	**Axis spacing** = Majaxis - Minaxis **(10)**	The difference between the axes allows us to make a clear difference between certain forms of erythrocyte.
Convex set	{(Ꞇ) is convex if ∀x, y∈Ꞇ ∀ t ∈ [0,1] tx+ (1-t)y ∈ Ꞇ} **(11)**	A set (Ꞇ) is said to be convex when any point x and y of the set describes a segment that is entirely part of the set.

- Colorimetric parameters

On a blood smear, red blood cells appear pinkish with a slight whitish area in the centre. A change in this appearance is usually indicative of a pathology. The proposed algorithm allows us to quantify all the pixels belonging to each area (pink or white). Indeed, the transformation of the colour image into a grey-level image followed by the application of Otsu's method combined with a two-class segmentation on the isolated cell, allowed us to highlight the two colours that make up the red cell (red represented by black and white) and to quantify them through the calculation of the image histogram. The histogram is a statistical graph that indicates the number of pixels per grey level.

The pixels thus grouped according to their grey level give rise to two regions R1 (red) and R2 (white) in healthy erythrocytes and in some binarized diseased erythrocytes. The ratio of these two quantified regions is an important piece of information in the formal characterization of certain anaemic forms. These two quantities are calculated automatically by the proposed method following the relationships below:

$$NbrePixelWhite = \sum_x \sum_y f(x,y) \text{ such that } I(x,y) = 255 \quad (12)$$

$$NbrePixelRed = \sum_x \sum_y f(x,y) \text{ such that } I(x,y) = 0 \quad (13)$$

NbrePixelsWhite and $NbrePixelRed$ indicate the pixel size of the white region and the pixel size of the red region of the binarized erythrocyte, respectively. In this binarization,

I(x, y) is the gray level value of the above-mentioned regions.

The determination of the proportion of distribution of pixels in each of the regions is obtained from the following equations:

$$PR = \frac{1}{aire} \sum_x \sum_y f(x,y) \text{ such that } (x,y) \in \boldsymbol{R1} \quad (14)$$

$$PB = \frac{1}{aire} \sum_x \sum_y f(x,y) \text{ such that } (x,y) \in \boldsymbol{R2} \quad (15)$$

PR is the percentage of distribution of pixels in the red region (R1) and PB is the percentage distribution of pixels in the white region (R2) in the binarized erythrocyte.

- Algorithm for testing the morphology of red blood cells

This section presents the subtlety developed for the detection of red blood cell geometry. The search for the morphology of red blood cells requires first of all knowledge of the compactness which makes it possible to differentiate in a first step a circular or elliptical shape from other shapes such as falciforms and acanthocytes. After learning, we find that the latter have a compactness of less than 0.8.

In a second step:

- If the compactness is greater than or equal to 0.8, we try to find out whether the red blood cell is circular or elliptical; under these conditions, we calculate the major and minor axes of the red blood cell, then we deduce the difference ***r*** between these two axes. If ***r*** is greater than 7 pixels then its shape is elliptical, otherwise it is circular.
- Otherwise, i.e. if the compactness is less than 0.8 then it is non-convex or concave. In this case, we calculate the barycentre of the hematite and then we look for the point furthest from it. Then, a square mask of variable side limited by the farthest point of the erythrocytes is generated. From the erythrocytes, we isolate the complementary of the intersection of the erythrocytes with the mask. This region is labelled in related components. When the number of components is greater than two, it is an acanthocyte form; conversely, if this number is equal to two, we detect a falciform form.

IV. Results and Discussions

The method of identifying the forms of red blood cell disease proposed through the flow chart in Fig. 3 allowed us to estimate the different morphological and colorimetric quantities from blood smear images obtained from different patients, both healthy and anaemic. These quantities allow us to clearly identify the different red blood cells, both healthy and diseased. Thus, this diagnosis will enable pathologists to propose appropriate treatments. Our samples come from anaemic and non-anaemic patients known through a blood count carried out by the existing automatons. Our method has made it possible to correct the insufficiencies of the automatons to effectively detect certain forms of anemia and certain pathologies linked to the morphological aspect and the color of the red blood cells, in particular sickle cell anemia, anemia due to alcoholic cirrhosis, hereditary elliptocytosis, etc. In this section, we present some of the results obtained. As well as their discussion on patients identified as healthy and anaemic by the count examination. It should be noted that the CBC scan does not indicate the precise form of anemia in the patient.

A. Analysis of the Results of our Application on a Healthy Patient

Following the selection of the target red blood cells through our application, Fig. 6 presents the steps of red blood cell isolation in a known healthy patient. In addition, Tables III and IV present the colorimetric and morphometric parameters, as well as the test of the geometry of the selected red blood cells which lead to the identification of the form of anemia or non-anemia of this patient.

From the colorimetric analysis, it appears from Table III that in a healthy red blood cell the pixels designating the red color indicating the presence of hemoglobin occupy 86 to 90% of the surface area of the red blood cell and the clear central area represents only 10 to 14% of the cell area. This finding is consistent with data in the literature. Morphologically, to show its circularity, we calculated the compactness of the cell and the distance r between the major and minor axes of the cell. For a healthy red blood cell that has a circular shape, the distance r between the major and minor axes is very small, i.e. less than 7 pixels, and the compactness is close to the value 1. This confirms the data in Table IV where the variable distance r varies between 2 and 6 with compactness values between 1.1 and 1.2. The normal colorimetric proportion in white and red pixels added to the estimation of the two previous parameters allow us to identify with certainty that the red blood cells of this patient are healthy.

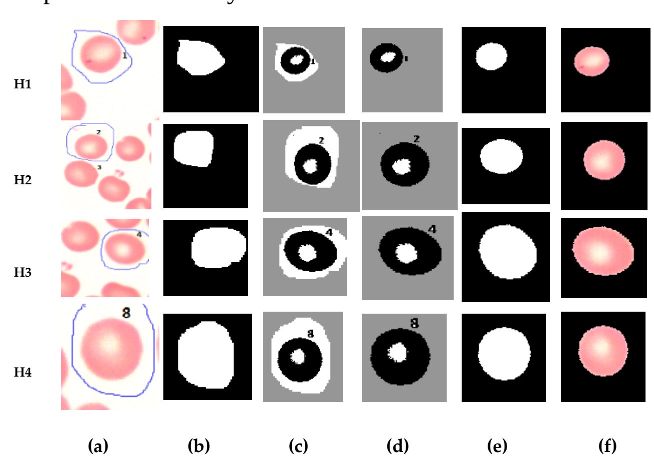


Fig. 6. (a) Region of Interest in the Source Image (b) Selection Area Binarized by Otsu's Algorithm (c) Erythrocyte Isolation (d) Segmentation into Two Classes (e) Isolated Segmented Erythrocyte (f) Isolated Source Erythrocyte.

TABLE III. COLORIMETRIC PARAMETERS OF HEALTHY RED BLOOD CELLS

	Class size		Color			Area	Distribution	
	Red Pixels	White Pixels	Red	Green	Blue	In pixel	% White	% Red
H1	3889	583	255	222	219	4472	13.03	86.94
H2	4321	618	255	222	219	4939	12.51	87.49
H3	4054	643	255	222	219	4697	13.69	86.31
H4	4253	469	255	222	219	4722	10.00	90.00

H1, H2, H3 and H4 represent red blood cells.

TABLE IV. MORPHOLOGICAL PARAMETERS OF HEALTHY RED BLOOD CELLS

	Com pac	**Area**	**Per i**	**Minor A**	**Major A**	**Spacin g**	**Varconve x**
H_1	1,22	4472	215	35.36	39.22	3.86	0
H_2	1,20	4939	231	37.40	41.04	3.63	0
H_3	1,13	4697	228	35.33	41.74	6.41	0
H_4	1,20	4722	224	37.02	39.73	2.71	0

Compact: compactness, Peri: Perimeter, MinorA: minor axis, MajorA: major axis, Spacing: difference between majoA and MinorA.

1) The results of our application on four anaemic patients: We present the diagnostic results of the forms of anemia of four (04) anaemic patients produced by our application. For clarity, we have named the patients from Patient 1 to Patient 4.

a) Analysis of Patient 1 results: The results from our application for Patient 1 shown in Fig. 7 and in Table VI show that the compactness of the red blood cells is between 0.9 and 1, confirming their circular shape. Moreover, the value of the deviation r of the axes below 7 pixels confirms this shape. Consequently, the red blood cells have a normal morphology.

The colorimetric characteristics of the red blood cells grouped in Table V indicate that the proportion in white pixels varies from 33.26% to 45.5% and the proportion in red varies from 54% to 66%. The maximum proportion, which is 66.79%, is below the standard for a healthy red blood cell, whose proportion varies between 86% and 90%. The observation made on the colorimetric characteristics is the best indicated for the identification of this form of red blood cell called annulocyte generally indicating a martial deficiency anemia.

b) Presentation of patient 2 results: Sickle cell anemia is a hereditary and anaemic disease that cannot be detected by the blood test performed by current automatic machines. This serious and painful disease deserves early management following a clear and precise diagnosis. Our proposed method fulfils these conditions because the examination of the blood smear facilitates the morphological study of the red blood cells. Since sickle cell disease transforms red blood cells into a particular form: sickle or lunar crescent, its detection on a smear is easier.

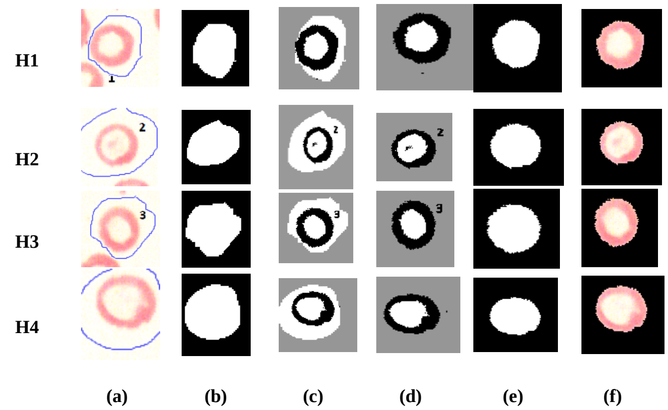


Fig. 7. (a) Region of Interest in the Source Image (b) Selection Area Binarized by Otsu's Algorithm (c) Erythrocyte Isolation (d) Segmentation into Two Classes (e) Isolated Segmented Erythrocyte (f) Isolated Source Erythrocyte.

TABLE V. COLORIMETRIC PARAMETERS FOR ANNULOCYTE CHARACTERIZATION

	Class size		Color			Area	Distribution	
	Red Pixels	White Pixels	Red	Green	Blue	In pixel	% White	% Red
H_1	2385	1186	255	232	221	3571	33.26	66.79
H_2	1913	1597	255	232	221	3510	45.50	54.50
H_3	2341	1248	255	232	221	3589	34.77	65.23
H_4	2021	1525	255	232	221	3546	43.00	57.00

TABLE VI. MORPHOLOGICAL PARAMETERS FOR ANNULOCYTE CHARACTERIZATION

	Com pac	**Are a**	**Per i**	**Mino A**	**Major A**	**Spacin g**	**Varconve x**
H_1	**0,93**	**3571**	**219**	**30.63**	**35.27**	**4.64**	**0**
H_2	**1,05**	**3510**	**205**	**30.87**	**34.82**	**3.95**	**0**
H_3	**0,91**	**3589**	**222**	**29.92**	**36.44**	**6.52**	**0**
H_4	**1,04**	**3546**	**207**	**29.51**	**36.14**	**6.63**	**0**

The colorimetric characteristics of red blood cells in Fig. 8 and grouped in Table VII show that the proportion of red pixels varies between 91% and 99%, which suggests the proportion of a healthy red blood cell. On the other hand, the morphological data in Table VIII indicate that the compactness, which varies from 0.5 to 0.7, shows us that these red blood cells are quite different from normal red blood cells whose compactness varies from 0.9 to 1 as shown in Table IV. Moreover, the difference r between the different axes confirms the non-normality of this form of red blood cell, since this difference r is around 35 pixels, which is much greater than the normal, which is less than 7 pixels. Also given the shape of the red blood cells in Fig. 8, we used the convex set principle for a formal identification of them. This is confirmed by the value of the varconvex variable in Table VIII, which takes the value 1 when it is a non-convex shape corresponding to the sickle cell morphology. Next, a square mask with a variable side bounded by the farthest point of the red blood cell. From the red blood cell, we isolate the complementary of the intersection of the red blood cell with the mask. This region is labelled in related components. When the number of components is equal to two as shown by the value of the variable NCC (number of related components) which is exactly 2, it is a sickle shape. This confirms the visual appearance of these red blood cells. Our method thus makes it possible to clearly identify the sickle cell red blood cells in order to institute a treatment protocol adapted for this type of anemia.

c) Presentation of patient 3 results: After the results obtained and indicated in Fig. 9, the different steps leading to the isolation of the selected red blood cell, we present in Tables IX and X the different colorimetric and morphological characteristics.

The analysis of the colorimetric parameters in Table IX shows a total absence of white pixels and the presence of 100% of the proportion of red pixels, which indicates an anomaly in the distribution of white and red pixels in a healthy red blood cell. Indeed, in a healthy red blood cell the proportion of white pixels varies between 10% and 14% of the total area of the red blood cell and the proportion of red pixels varies between 86% and 90% as shown in Table III.

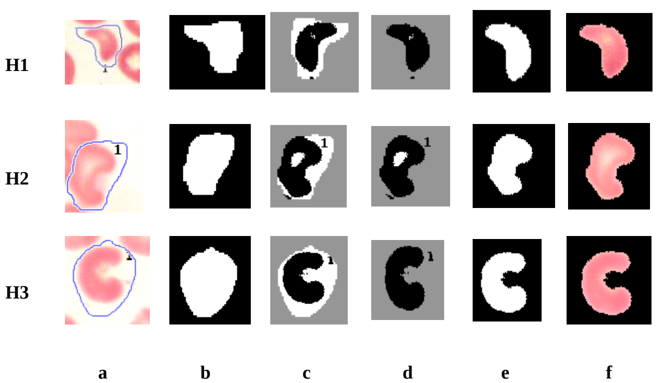


Fig. 8. (a) Region of Interest in the Source Image (b) Selection Area Binarized by Otsu's Algorithm (c) Erythrocyte Isolation (d) Segmentation into Two Classes (e) Isolated Segmented Erythrocyte (f) Isolated Source Erythrocyte.

TABLE VII. SICKLE-CELL COLORIMETRIC PARAMETER

	Class size		Color			Area	Distribution	
	Red Pixels	White Pixels	Red	Green	Blue	In pixel	% White	% Red
H_1	2022	15	253	214	204	2037	0.73	99.27
H_2	3547	291	255	213	206	3838	08.20	91.8
H_3	3789	2	255	218	215	3791	0.05	99.95

TABLE VIII. SICKLE-CELL MORPHOLOGICAL PARAMETERS

	Com pac	Area	Peri	MinorA	MajorA	Spacing	varc onve x	NC C
H_1	0.67	2037	195	8.49	40.49	32.00	1	2
H_2	0.76	3838	252	12.21	47.40	35.19	1	2
H_3	0.53	3791	300	10.24	45.93	35.69	1	2

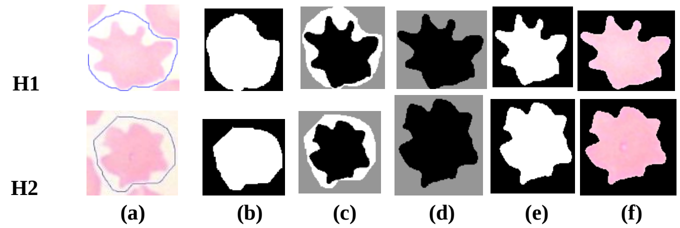


Fig. 9. (a) Region of Interest in the Source Image (b) Selection Area Binarized by Otsu's Algorithm (c) Erythrocyte Isolation (d) Segmentation into Two Classes (e) Isolated Segmented Erythrocyte (f) Isolated Source Erythrocyte.

TABLE IX. COLORIMETRIC PARAMETERS OF ACANTHOCYTES

	class size		Color			Area	Distribution	
	Red Pixels	White Pixels	Red	Green	Blue	In pixel	% Blanc	% Rouge
H_1	6489	0	254	222	229	6489	0	100
H_2	5785	0	254	222	229	5785	0	100

TABLE X. MORPHOLOGICAL PARAMETERS OF ACANTHOCYTES

	Com pac	**Area**	**Peri**	**MinoA**	**MajoA**	**Spaci ng**	**varc onve x**	**NC C**
H_1	0.57	6954	378	24.41	66.43	42.02	1	4
H_2	0,78	5785	306	30.30	51.58	21.28	1	6

At the morphological level, the analysis of Table X gives a compactness value of 0.5 to 0.7. This variation is almost identical to the compactness of the sickle shapes as shown in Table VIII. This confusion is also observed at the level of the deviation r of the major and minor axes of the erythrocyte which is between 21 pixels and 41 pixels. So, for an accurate identification of this form of red blood cell, we used our red blood cell morphology testing algorithm described in section above. The value of the variable NCC which indicates the number of related components obtained by labelling the areas in related components following the intersection of the cell with the mask. In our coding, when the number of related components is greater than two (02) then we detect an acanthocyte which is the form of red blood cell disease observed in hepatic cirrhosis and in congenital acanthocytosis which is a haemolytic anemia related to abnormal phospholipid metabolism [1]. This confirms our expected results.

d) Presentation of patient 4 results: Elliptocytes are elongated, oval, or ellipsoid red blood cells with rounded ends Fig. 10.

Table XI shows the colorimetric characteristics of elliptocytes. On analysis of the data, we find that the proportion of white pixels varies between 17% and 41%, indicating the presence of annulocytes. Analysis of the morphological data in Table XII shows a certain similarity between some forms of red blood cells and elliptocytes, as the compactness is between 0.9 and 1 and indicates the same range as that of healthy red blood cells and annulocytes. Indeed, compactness alone does not allow elliptocytes to be characterized. To solve this problem, we have calculated the interval r of the red blood cell count. This deviation between

25 and 30 pixels is greater, unlike the deviation on annulocytes, which is less than or equal to 7. So, the identification of elliptical shapes is precise by combining the compactness, and the distance r between the two axes. This combination allows our algorithm to accurately detect elliptocytes. In addition, we can look at the distribution of white and red pixels which indicates another form of anaemia. As a result, the patient may suffer from 2 or more forms of anemia.

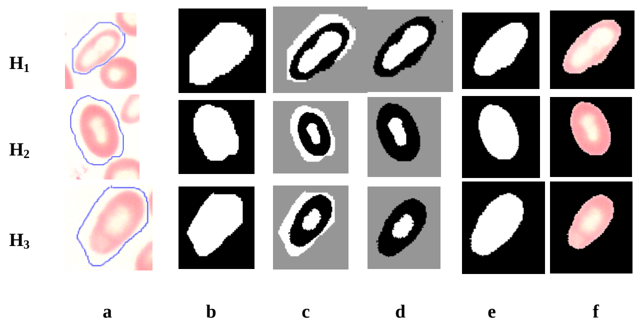


Fig. 10. (a) Region of Interest in the Source Image (b) Selection Area Binarized by the Otsu Algorithm (c) Isolation of the Erythrocyte (d) Segmentation into Two Classes (e) Isolated Segmented Erythrocyte (f) Isolated Source Erythrocyte.

TABLE XI. COLORIMETRIC PARAMETERS OF ELLIPTOCYTES

	Class size		Color			Area	Distribution	
	Red Pixels	White Pixels	Red	Green	Bblue	In pixel	% White	% Red
H_1	2297	1628	255	233	228	3925	41.45	58.55
H_2	3637	771	255	233	228	4408	17.50	82.50
H_3	3449	784	255	233	228	4233	18.52	81.48

TABLE XII. MORPHOLOGICAL PARAMETERS OF ELLIPTOCYTES

	Compc	**Area**	**Peri**	**MinoA**	**MajoA**	**spacing**	**varconvex**
H_1	0,90	3925	236	23.29	52.64	29.36	0
H_2	1.09	4408	225	28.51	53.51	25.00	0
H_3	1,02	4233	228	25.00	51.60	26.60	0

V. CONCLUSION

In this document, we have proposed a new method for identifying the different forms of red blood cells through color microscopic images of blood smears taken from anaemic patients. The proposed method is based on a selection of different regions of interest each containing a target red blood cell to which we apply the application developed in this work in order to extract morphological and colorimetric parameters for the different related red blood cells. Moreover, the application allows the precise identification of certain types of anemia. This formal identification allows pathologists to improve the diagnosis and establish a treatment protocol adapted to each type of anemia. This work, whose objective is to contribute to improving the well-being of our populations, cannot stop there because the list of pathologies, whether anemic or not related to the color and morphology of red blood cells, is still long. In the future, we will continue the detection of new forms of red blood cell disease not studied here in order to improve our semi-automatic diagnostic application.

Our future work concerns the following points:

- Development of algorithms to detect cells whose outline is not clear.
- Determine erythrocyte inclusions: Heinz bodies, Howell-Jolly bodies, etc.
- Determine a threshold at which the diagnosis of the type of anemia will be clearly made.
- Considerably reduce the rendering time of the results.
- Extend our method to other types of biological examinations that are still difficult to perform in our laboratories.

Data Availability: The figures and images used to support the results of this study are included in the article.

Conflicts of Interest: The authors declare no conflict of interest.

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Enhanced Artificial Intelligence System for Diagnosing and Predicting Breast Cancer using Deep Learning

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***Abstract*—Breast cancer is the leading cause of death among women with cancer. Computer-aided diagnosis is an efficient method for assisting medical experts in early diagnosis, improving the chance of recovery. Employing artificial intelligence (AI) in the medical area is very crucial due to the sensitivity of this field. This means that the low accuracy of the classification methods used for cancer detection is a critical issue. This problem is accentuated when it comes to blurry mammogram images. In this paper, convolutional neural networks (CNNs) are employed to present the traditional convolutional neural network (TCNN) and supported convolutional neural network (SCNN) approaches. The TCNN and SCNN approaches contribute by overcoming the shift and scaling problems included in blurry mammogram images. In addition, the flipped rotation-based approach (FRbA) is proposed to enhance the accuracy of the prediction process (classification of the type of cancerous mass) by taking into account the different directions of the cancerous mass to extract effective features to form the map of the tumour. The proposed approaches are implemented on the MIAS medical dataset using 200 mammogram breast images. Compared to similar approaches based on KNN and RF, the proposed approaches show better performance in terms of accuracy, sensitivity, spasticity, precision, recall, time of performance, and quality of image metrics.**

Keywords—Traditional Convolutional Neural Network (TCNN); Supported Convolutional Neural Network (SCNN); shift; scaling; cancer detection; mammogram; histogram equalization; adaptive median filter

I. Introduction

The use of artificial intelligence (AI) in the medical sector has many benefits. In light of the danger of spreading COVID-19, machine learning plays a significant role in limiting the number of infected people. The reason is that AI reflects an automation process that can be performed by machines on behalf of users (i.e. doctors, nurses, or medical staff in the medical sector) in regard to diagnosis [1, 2]. Another benefit of AI in the medical sector is the lowering of the cost of treatment and enhancement of the chance of survival [3, 4]. Early breast cancer detection is an excellent example to support this argument in this context. In general, 10 AI applications and advantages can be exploited for the sake of serving humanity, as illustrated by the 2026 estimation in Fig. 1.

Statement of problem. One of the most important causes of the increased death ratio among women society (in contrast to men) is breast cancer. Research has shown that the number of people who died due to breast cancer continued to increase from 2007 to 2018, as shown in Fig. 2.

From a medical point of view, the early detection of breast cancer contributes to saving the lives of patients as well as decreasing the cost of treatment at both the private and governmental medical institution levels. Computer science researchers have employed AI for this purpose, and many approaches have been proposed, such as [7-21]. However, the quality of any proposed approach for breast cancer detection is evaluated based on its accuracy. In other words, due to the sensitivity of diagnosis in the medical field, a high error rate is critical and may lead to death. In the context of AI, the error rate is represented by the false positive (FP) cases that the intelligent machine fails to classify correctly [22, 23]. In real life, it is harmful for the patient to provide a diagnosis result of negative while the diagnosis is actually positive. It is worth mentioning that most of works reviewed in the related work section suffer from this problem. Fig. 3 illustrates the problem being addressed in this work.

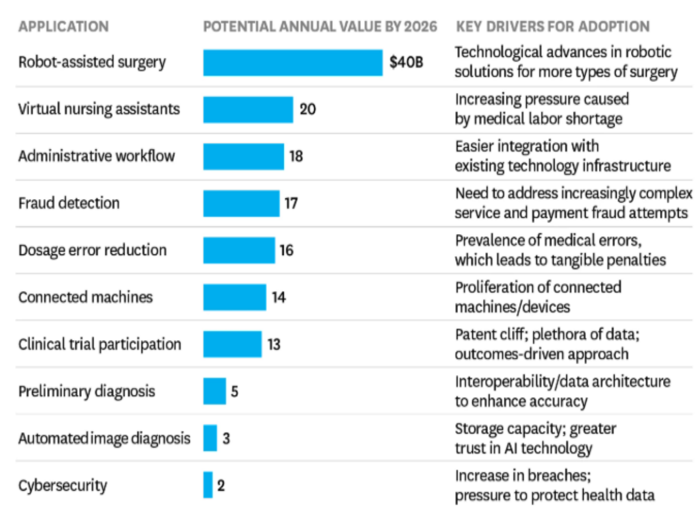


Fig. 1. Benefits of 10 AI Applications in 2026 [5].

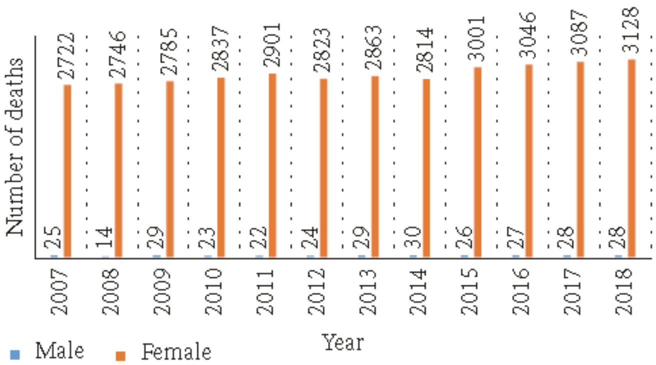


Fig. 2. Statistical Survey for Death caused by Breast Cancer [6].

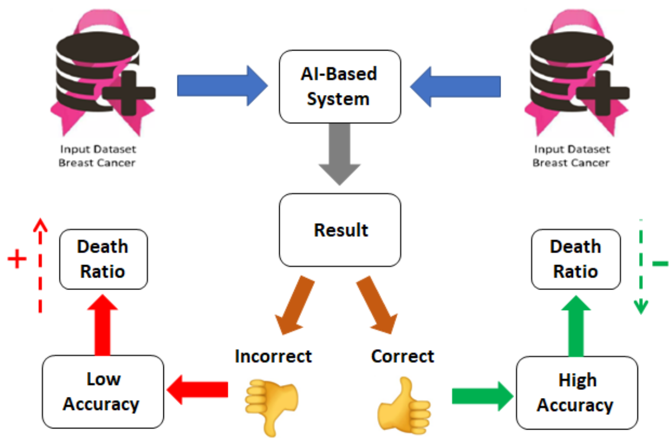


Fig. 3. Problem of AI-based Breast Cancer Detection Systems.

Research questions. On one hand, mammography images are common in hospitals and used for breast cancer detection. On the other hand, image blurring is a recognized issue in the UK [24, 25]. Blurry mammography images are considered the root cause of lower accuracy in AI-based diagnosis systems if they are used to train a classifier. Blurry images are generated because of breast/paddle movement while the exposure is being made [26, 27]. There are also other contributors that negatively impact the clarity of mammography images and are related to inadequate compression, and patient movement together with long exposures may also cause blurring [28]. Such blurring may cause distortion of the generated mammography images in terms of shift and scaling. Therefore, the main research question is how to ensure that AI-based systems generate diagnosis results with high accuracy for noisy mammography images. This in turn leads to the following two questions:

1) How can AI-based systems detect cancer in the breast even if a mammography image has a shift problem?

2) How can AI-based systems control the scaling problem so that it does not affect the accuracy of the detection system?

Using conventional neural networks (CNNs) can contribute to answering the previous questions and lead to better accuracy. That is because we can exploit the architecture of the CNN to control the shifting problem based on conventional layers, while the scaling problem can be absorbed by pooling functions.

In general, the contributions of this works can be listed as follows:

- In responding to the shift problem caused by blurring in mammography images, the architecture of the CNN technique is employed. The padding operation is used in the proposed Traditional convolution neural network (TCNN) to overcome this problem.
- To solve the scaling problem caused by blurring in mammography images, the architecture of the CNN technique is employed. The max function used in the proposed supported convolution neural network (SCNN) to construct the pooling layers is used to overcome this problem.
- To increase the accuracy of the classification process, the flipped rotation-based approach (FRbA) is introduced.
- Extensive experiments are conducted to show the effectiveness of the proposed methods and compare with similar approaches.

The rest of this work is organized as follows. Section II reviews the related work. Section III provides the proposed CNN classification model. In Section IV, the used metrics are presented for evaluation purposes. Section V presents the experiments and discusses the results in light of a comparison with similar approaches. Finally, the paper is concluded in Section VI.

II. Related Work

This section provides a brief background regarding the domain we stand on, followed by a review of approaches that have previously been proposed in the breast cancer detection research field under the AI umbrella.

A. Background

The domain that addresses breast cancer diagnosis, in terms of AI, can be represented by an intersection of four main disciplines, as shown in Fig. 4.

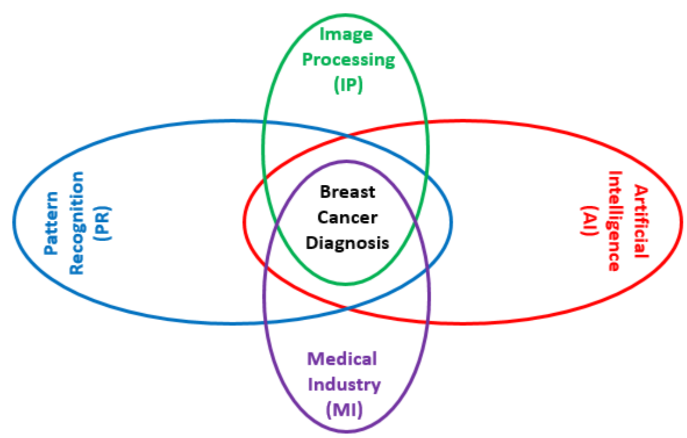


Fig. 4. Intersection of Disciplines that Represent Breast Cancer Diagnosis.

Fig. 4 shows that AI, image processing (IP), medical industry (MI), and pattern recognition (PR) disciplines are involved in the breast cancer diagnosis research field. AI is defined as the science that studies the capability of granting machines the ability to make decisions on behalf of humans [29]. IP is defined as methods of performing some mathematical operations on images based on computer algorithms to obtain improved images or extract various information or features related to the images [30]. PR can be seen as automated learning algorithms that are used to identify patterns such that data are classified into various groups or categories based on the information extracted from the patterns [31]. As for MI, it is a sector within the economic system that provides goods and services to treat patients with curative, preventive, rehabilitative, and palliative care [32].

B. Taxonomy of AI-based Approaches for Breast Cancer Diagnosis

Many efforts have been made to group AI-based systems concerning breast cancer detection, such as [6] and [33-35]. Ref [6] provides details about the description of breast cancer image classification techniques, feature extraction and selection procedures, classification measurement parameterizations, and image classification findings. In addition, it focuses on analysing three main techniques, which are the CNN, random forest (RF), and support vector machine (SVM). The authors of [33] present classification from a medical point of view (i.e. relying on types of cancer) along with four popular architectures used for cancer detection and diagnosis, which are CNN, fully convolutional networks (FCNs), auto-encoders (AEs), and deep belief networks (DBNs). In [34], the authors aim to investigate the state of the art regarding computer-aided diagnosis/detection (CAD) systems for breast cancer by presenting a systematic review. What makes this work recognizable is the good presentation of the databases available for conducting experiments for breast cancer detection. In terms of advantages and disadvantages, [35] summarizes a wide spectrum of the approaches for breast cancer detection. In addition, the performance of the reviewed approaches is investigated and analysed.

In this research, we classify the techniques used for breast cancer detection in the domain of AI based on the three main groups used in this science. Fig. 5 illustrates the supervised, unsupervised, and semi-supervised groups, where each category has its own techniques/algorithms.

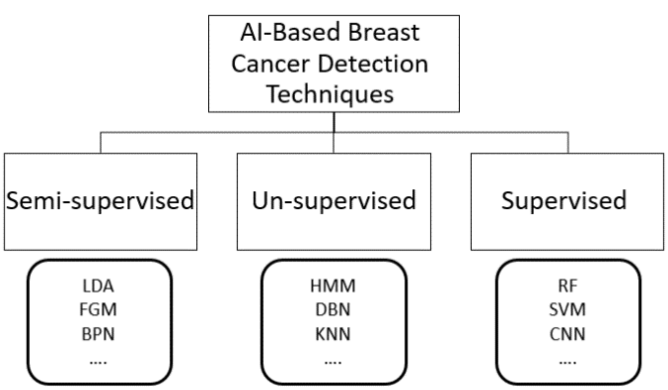


Fig. 5. Groups of AI-based Systems.

1) Supervised learning-based group: Using some data mining techniques, a comparison study is presented in [7] with the goal of identifying the best technique for breast cancer detection. The authors apply RF, SVM, and Naïve Bayes (NB) on two different data sets, which are INbreast and Breast Cancer Digital Repository (BCDR). The findings show that the RF method is ranked at the top with an accuracy value of 78.3%.

In [8], a super-resolution (SR) approach is proposed that exploits the complementary information provided by multiple images of the same target. In this work, the CAD system consists of four stages: (1) SR computation; (2) extraction of the region of interest; (3) feature extraction; and (4) classification. It is worth mentioning that the authors focus on methods for extracting texture features from a single breast ultrasound (BUS) image for each breast, which mainly suffers from speckle noise and artefacts. As for the dataset used to conduct experiments, the authors used a dataset named Ultrasound Images Private (31 malignant, 28 benign). The proposed CAD system achieves a value of 0.99 in terms of the area under the receiver operating characteristic (ROC) curve (AUC).

The objective of [9] is to evaluate the performance of a system for the detection of masses based on blind feature extraction using independent component analysis (ICA). The system uses different classifiers, such as neural networks (NNs) and SVMs. A conversion process of the image to optical density is performed first as a processing stage. Later, the regions of interest are appropriately resized to facilitate the task of the feature extractor. Finally, the classifiers are applied to detect and classify masses in the mammograms images. The Digital Database for Screening Mammography (DDSM) database is used (5052 images) in this work for training and testing. According to AUC-based evaluation, the proposed method achieves a value of 0.937.

The method presented in [10] aims to help medical experts in the classification of breast cancer lesion through the implementation of Convolutional Neural Network Improvement for Breast Cancer Classification (CNNI-BCC). In their method, the authors 1) decompose the images into patches; (2) have each patch process non-rectangular regions in the image via the masking of certain areas; (3) train on small data sets with a combined rained CNN; and (4) have the presented CNNI-BCC utilize the patch feature relevance to detect and classify the lesion region. The approach is tested using the Mammography Image Analysis Society (MIAS, 221 images) dataset and achieves 90.50% accuracy.

The goal of [11] is to propose a prototype of a medical expert system (based on data mining techniques) that can significantly aid medical experts in detecting breast cancer. The proposed system consists of four major steps: (1) image processing using the discrete wavelet transformation (DWT); (2) extraction of features of the region of interest (ROI); (3) formation of a total of 20 grey level co-occurrence matrix (GLCM) features from the ROI, which are in turn used as inputs for classification algorithms; and (4) application of the actual classification process, where seven different classifiers are used, i.e., SVM, RF, C4.5, K-nearest neighbour (KNN), naive Bayes (NB), logistic regression (LR), and multilayer perceptron (MLP). In this study, normal breast images and breast images with masses (322 images in total) are manipulated in the training and testing phases. The images are taken from the MIAS database. The SVM and MLP methods achieve accuracies of 74% and 76%, respectively.

A conditional generative adversarial network (cGAN) approach is proposed in [12]. The key idea is to segment the breast tumour within an ROI in mammogram images. The generative network learns to recognize the tumour area and to create the binary mask that outlines it. Experiments are conducted on two datasets, the public INbreast and a private in-house dataset. The proposed segmentation model provides a high dice coefficient and intersection over union (IoU) of 94% and 87%.

2) Unsupervised learning-based Group: Relying on both the wavelet and the hidden Markov model (HMM), a breast cancer detection-based system is provided in [13]. The key idea behind the detection is to identify suspicious areas of breast cancer tumours. Mammographic images are used in this work and processed using a median filter to extract image features. This step is performed to clarify and improve the quality of mammographic images. A combination of MIAS and Paden databases is used to test the proposed method. The detection rate of the proposed method is 96%.

In [14], Al-antari et al. proposed a deep belief network (DBN)-based CAD system to classify breast tissues. Three classes are used in the classification process, which are normal, benign, and malignant. What distinguishes this work is the automatic mass detection algorithm for identifying suspicious masses on mammograms. Then, statistical features are derived from the detected masses. The authors used the DDSM dataset (150 images). The overall accuracies of a DBN are 92.86% and 90.84% for the two ROI techniques, respectively.

Depending on the clustering principle, a microcalcification cluster enhancement method is presented and implemented on digital mammogram images in [15]. The authors handle the dependence problem via the segmentation phase, where a Laplacian of Gaussian filter (LoG) is employed. This leads to optimization of the recognition efficiency. As for the clustering method, fuzzy C-means (FCM) is utilized. The authors used the MIAS dataset to build the detection system. The method is evaluated in terms of accuracy and achieves 95%.

In [16], instead of working in the spatial domain, the authors deal with the frequency domain using a discrete curvelet transform to extract features of the images (image map). The medical images used in this work are mammogram images, and the manipulation passes through three main steps. First, the discrete curvelet transform is applied to the images to compute the four first-order moments. Consequently, two feature sets are obtained: moments from each band and moments from each level. Second, the t-test ranking technique is applied to select the best features from each set. Finally, the KNN classifier is used to distinguish between normal and abnormal breast tissues and classify tumours as malignant or benign. Experiments are performed depending on both the MIAS (252 images) and DDSM (11,553 images) datasets. The results on the mini-MIAS database show that curvelet moments yield an accuracy of 91.27%.

Focusing on obtaining good mammogram images as an objective, the authors of [17] present the connected component labelling analysis (CCL), which is a multi-level segmentation approach based on artefacts and pectoral muscle removal to ensure good clarity of mammogram images. For the feature extraction and classification stages, they use statistical and Kernel self-optimized fisher discriminant (KSFD) methods, respectively. The MIAS dataset is utilized to implement the proposed approach and conduct the experiments. The KSFD method exhibits an accuracy of 94.46%.

3) Semi-supervised learning-based Group: Ganesan et al. [18] propose a framework for the automated detection of normal, benign, and cancerous mammograms. They rely on using a combination of texture, higher-order spectra (HOS), and discrete wavelet transform (DWT) for feature extraction from digitized mammograms. These features capture the subtle variation in the pixel intensities and contours in the images and serve as significant indicators for the classification process. Decision tree (DT), Fisher, linear discriminant classifier (LDC), nearest mean classifier (NMC), Parzen, and SVM classifiers are used to classify the features. Among the classifiers evaluated, DT performs the best. The accuracy of the proposed method is 91.6% for the DDSM database and 96.8% for SATA.

The goal of [19] is to introduce a classification algorithm based on the fuzzy Gaussian mixture model (FGMM). This is achieved by combining the power of the Gaussian mixture model (GMM) and fuzzy logic system (FLS) to build a CAD system. This system is responsible for classifying the detected regions in mammogram images into malignant or benign categories. The dataset used for this work is a subset of the DDSM (300 images). The results show that the proposed FGMM classifier has achieved an overall accuracy of prediction of 93%.

A tool for the diagnosis of mammography abnormalities is proposed in [20]. The key idea is to depend on semi-supervised classification using a transductive support vector machine (TSVM) with different kernel functions and heterogeneous feature families. The DDSM database (200 images) is used to implement the proposed approach and obtain the results. The TSVM method exhibits an accuracy of 93.1%.

The rough set theory (RST) method is provided in [21]. The RTS is used for many functions. First, it is integrated with back-propagation to handle more uncertain data. Second, RST has also been used to remove pectoral muscles and segmentation. As for artefacts and labels, they are removed using a vertical and horizontal sweeping method. Mammogram images are acquired from the MIAS database. Features are extracted from the segmented mammogram image using GLCM, GLDM, SRDM, NGLCM, and GLRM. Finally, the features are normalized, discretized, and then reduced using RST (as the third and final function of RST). After that, the classification is performed using RNN. The RNN classifier achieves a 99.2% overall classifying accuracy.

III. Proposed Approach

In this work, we propose two approaches for breast cancer detection, illustrating the impact of image processing on the accuracy of the classification process. The first approach is called the traditional CNN (TCNN)-based approach. The second is called the supported CNN (SCNN)-based approach. Both the TCNN and SCNN approaches follow the same steps shown in Fig. 6.

As shown in Fig. 6, there are 6 steps in the proposed approaches, starting with selection of the dataset and finishing with the output (i.e., the type of breast cancer). It is worth mentioning that the difference between the TCNN and the SCNN is highlighted by step 2 (image pre-processing).

In general, the system that implements the proposed approaches has an input and output. The input is a mammogram image, while the output is one of the three types of cancer (normal, benign, and malignant). Mathematically, x_{image}^{mam} refers to the input image, $\mathrm{y_{type}}$ refers to the output of the system (classifier), and $S = \{N.B.M\}$ is the set of the types of cancer. Then, the classifier is modelled as:

$$Classifier\left(x_{image}^{mam}\right) = y_{type} | type \in S \tag{1}$$

A. Selecting the Dataset

Due to the sensitivity of the medical area, it is difficult to access real medical images to conduct experiments. The sensitivity of the medical area is reflected by a high level of security and privacy issues [36-43]. In this work, the data are taken from the MIAS [44]. Table I summarizes the information of the MIAS dataset.

B. Image Pre-Processing

The objective of this step is to enhance the quality of the mammogram images. This in turn leads to higher classification accuracy. The reason behind this is that, the clearer edges and details are, the greater the ability to identify the area of the tumour is, and consequently the more accurate diagnosis is.

Formally, let x_{image}^{en-mam} denote the enhanced mammogram image (i.e. the image after the pre-processing step). Then, both the TCNN and SCNN approaches use the same x_{image}^{en-mam} symbol as an output of the pre-processing step. However, the mechanism of generating the enhanced mammogram image differs, as shown in Fig. 7.

In the TCNN approach, the input mammogram image x_{image}^{mam} is processed using the Histogram Equalization ($HisE$) function to generate the enhanced mammogram image according to:

$$HisE\left(x_{image}^{mam}\right) = x_{image}^{en-mam} \tag{2}$$

HisE is defined as a technique for adjusting image intensities to enhance contrast [45]. Mathematically, let f be a given image represented as an $\mathrm{m_r}$-by-$\mathrm{m_c}$ matrix of integer pixel intensities ranging from 0 to $\alpha - 1$. α is the number of possible intensity values, often 256. Let p denote the normalized histogram of f with a bin for each possible intensity. Thus,

$$p_i = \frac{number\ of\ pixels\ with\ intensity\ i}{total\ number\ of\ pixels} \quad i = 0.1.\ldots.\alpha - 1 \tag{3}$$

The histogram equalized image ($img = x_{image}^{mam}$) will be defined by

$$img_{a.b} = floor((\alpha - 1) \times \sum_{i=0}^{f_{a.b}} p_i) \tag{4}$$

where $floor()$ rounds down to the nearest integer.

Fig. 8 shows the impact of the $HisE$ function on the original breast mammogram image.

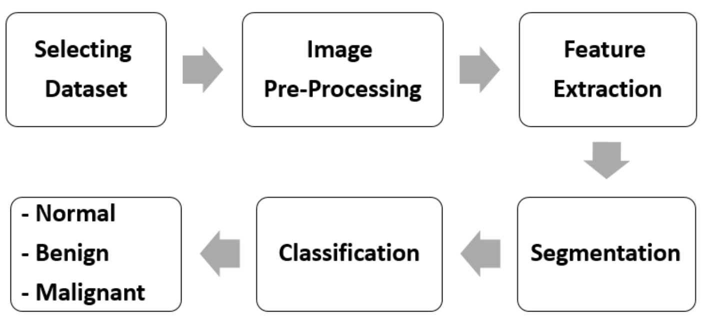


Fig. 6. Flowchart of the Proposed Approaches.

TABLE I. MIAS Dataset Description

<table>
<tr><td>NO of Images</td><td colspan="15">322 images</td></tr>
<tr><td rowspan="2">Type</td><td colspan="3" rowspan="2">Normal</td><td colspan="12">Abnormal</td></tr>
<tr><td colspan="5">Benign</td><td colspan="7">Malign</td></tr>
<tr><td>Abnormal Categories</td><td>Circumscribed Masses</td><td colspan="2">Spiculated Masses</td><td colspan="3">Microcalcifications</td><td colspan="4">Ill-defined Masses</td><td colspan="3">Architectural Distortion</td><td colspan="2">Asymmetry</td></tr>
<tr><td>Size</td><td colspan="15">1024×1024 pixels</td></tr>
<tr><td>Accuracy</td><td colspan="15">8-bit accuracy (grey level)</td></tr>
<tr><td rowspan="2">Location Information</td><td colspan="2" rowspan="2">Centre of a circle surrounding the tumour</td><td colspan="2" rowspan="2">Radius</td><td colspan="3">Breast Position</td><td colspan="5">Type of breast tissues</td><td colspan="3">Tumour type</td></tr>
<tr><td>Left</td><td colspan="2">Right</td><td colspan="2">Fatty</td><td colspan="2">Fatty-glandular</td><td>Dense</td><td colspan="2">Benign</td><td>Malign</td></tr>
</table>

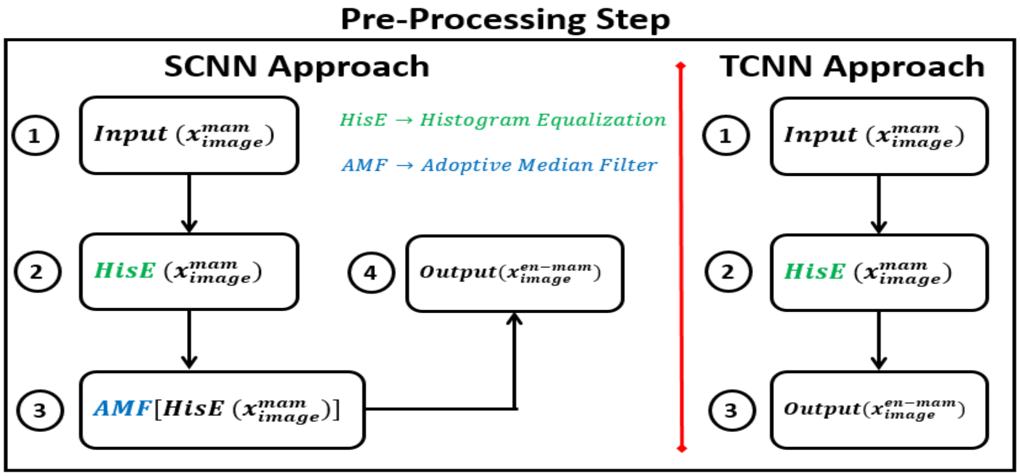
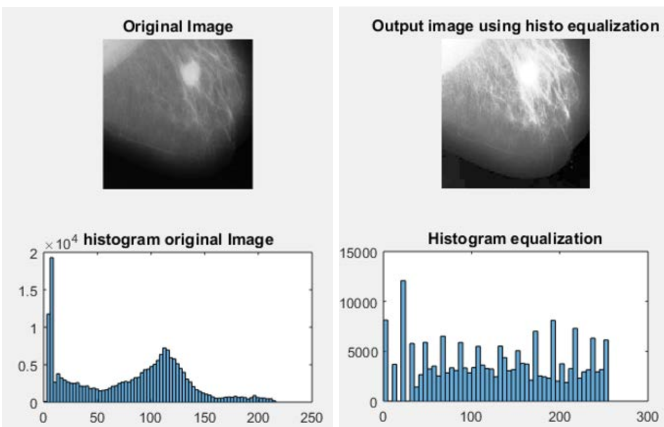
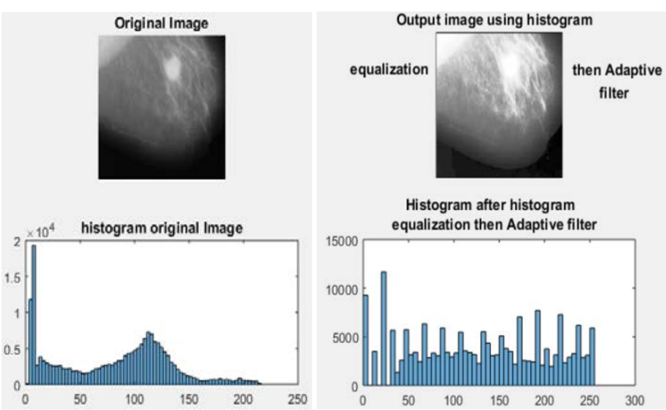


Fig. 7. Details of the Pre-Processing Step for Both the TCNN and SCNN Approaches.



(a) (b)

Fig. 8. Breast mammogram image after applying HisE. (a) The original image with the corresponding histogram. (b) The details of the breast are clearer; however, some blurring is generated due to HisE.



(a) (b)

Fig. 9. Breast mammogram image after applying AMF (HisE). (a) The original image with the corresponding histogram. (b) The image after enhancement is performed using AMF.

The AMF algorithm works in two levels, denoted as level alpha (α) and level beta (β), as follows.

Where we take into consideration the following notations arranged in Table II, we define the AMF algorithm.

Algorithm 1: Adoptive Median Filter (AMF)

begin
  Label Level α:
    begin
      $\alpha_1 = In_{med} - In_{min}$;
      $\alpha_2 = In_{med} - In_{max}$;
      if $\alpha_1 > 0$ and $\alpha_2 < 0$ then
        begin
          go to level β;
        end;
      else increase the w_{xy};
      if $w_{xy} \leq w_{max}$ then
        begin
          repeat level α;
        end;
      else output In_{med};
    end;
  label Level β:
    begin
      $\beta_1 = In_{xy} - In_{min}$;
      $\beta_2 = In_{xy} - In_{max}$;
      if $\beta_1 > 0$ and $\beta_2 < 0$ then
        begin
          output In_{xy};
        end;
      else output In_{med};
    end;
end;

TABLE II. NOTATIONS USED FOR AMF

Notation	Description
w_{xy}	Rectangular window area.
In_{min}	Minimum intensity value in w_{xy}.
In_{med}	Median of intensity values in w_{xy}.
In_{xy}	Intensity value at coordinates $(x.y)$.
In_{max}	Maximum intensity value in w_{xy}.
w_{max}	Maximum allowed size of w_{xy}.

In the SCNN approach, a further enhancement is performed using an adaptive median filter (AMF), as shown in Fig. 9 above. Since the blurring generated by $HisE$ can be considered as a kind of noise or distortion, AMFs contribute by adding additional enhancement for the mammogram input images. That is because they have the following benefits [46]:

1) Removal of salt and-pepper (impulse) noise.
2) Smoothing of other noise (may not be impulsive).
3) Reduction of distortion, such as excessive thinning or thickening of object boundaries.

In the SCNN approach, the input mammogram image $HisE\ (x^{mam}_{image})$ is processed using the AMF function to generate the enhanced mammogram image according to:

$$AMF[HisE\ (x^{mam}_{image})] = x^{en-mam}_{image} \quad (5)$$

C. Feature Extraction

In general, feature extraction techniques have some advantages as listed below:

1) Accuracy improvements.
2) Overfitting risk reduction.
3) Acceleration of training.
4) Improved data visualization.
5) Increase in explainability of our model.

The basic objective of the feature extraction step is to reduce the number of features in a dataset by creating new features from the existing ones (and then discarding the original features). This new reduced set of features should then be able to summarize most of the information contained in the original set of features [47].

In the CNN architecture, feature extraction is achieved by forming conventional layers. In depth, the conventional layers are generated by scanning the mammogram input image by a certain kernel (filter). Fig. 10 illustrates the architecture of the CNN as well as the general mechanism used to generate conventional layers.

The more features extracted, the greater the ability of the CNN model to define and classify the Region of Interest (RoI), where RoI refers to the cancerous mass. Depending on the previous fact, a flipped rotation-based approach (FRbA) is proposed to generate more useful features. The key idea behind the FRbA is to apply rotations as mathematical operations to give different views of the cancerous mass located within the mammogram input image. Fig. 11 shows the general idea of the FRbA.

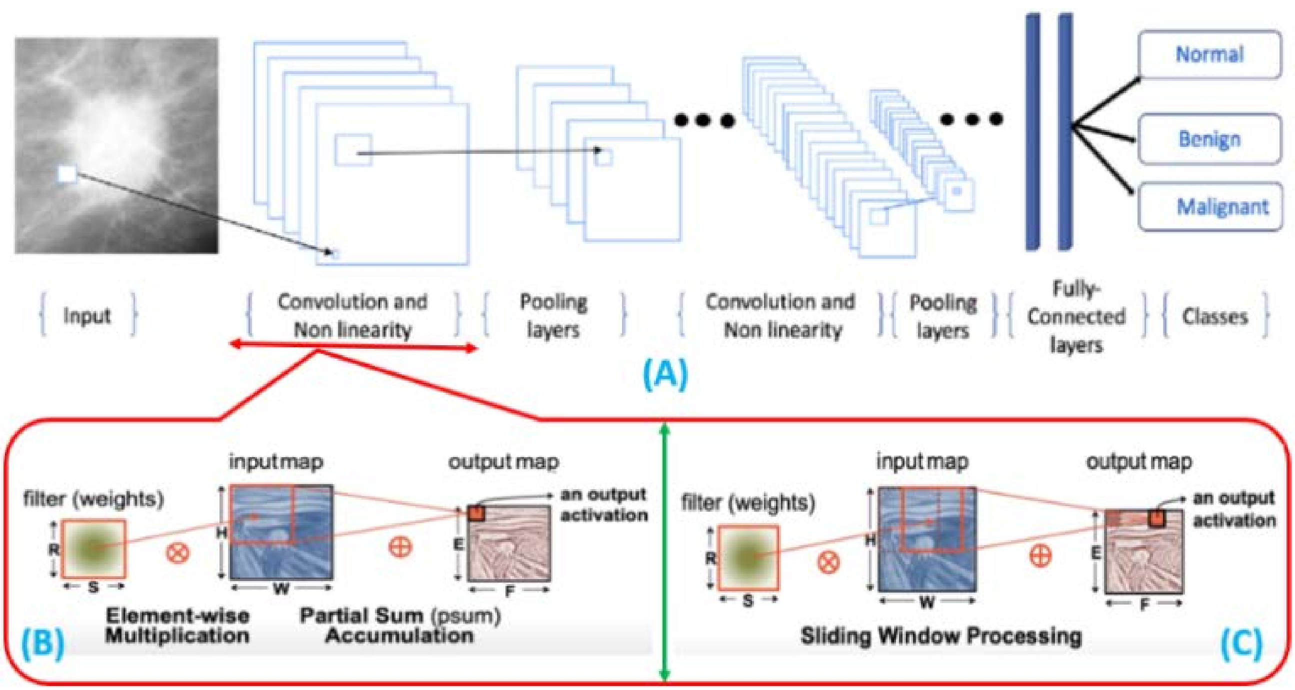


Fig. 10. Architecture of the CNN with Details of Forming Convolution Layers. (A) Represents the General Structure of the CNN model, where many Convolution Layers are Generated. (B) Illustrates the First Step of the Mechanism used to form the Convolution Layers. The Kernel (Filter) is Applied on the Image by Calculating the Sums of Multiplications (i.e. Multiplying the Weights of the Filter by the Intensity Values of the Input Mammogram Image and then Summing the Multiplications). (C) Illustrates the Sliding Window of the Filter to Scan the Entire Image, Covering all of the Pixels of the Image.

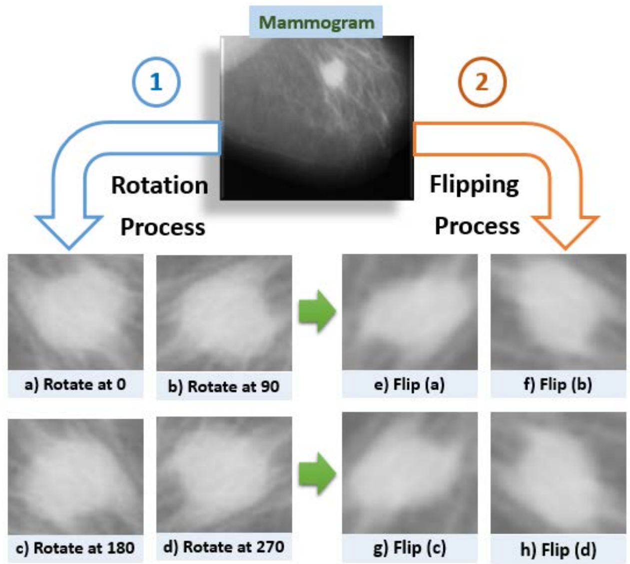


Fig. 11. General view of the FRbA.

Algorithm 2 shows the pseudocode of the FRbA in steps.

Algorithm 2: Flipped Rotation-based Approach (FRbA)

```
begin
    Read Input ( x^{b-mam}_{image} , x^{m-mam}_{image}, x^{n-mam}_{image});
    Pre-process ( x^{b-mam}_{image} , x^{m-mam}_{image}, x^{n-mam}_{image});
    ( x^{b-mam}_{image} , x^{m-mam}_{image}, x^{n-mam}_{image}) subsample
      according to transformation ;
    For (x^{b-mam}_{image}) , ROTATE to 90º, 180º, and 270º;
    For (x^{m-mam}_{image}), ROTATE to 90º, 180º, and 270º;
    For (x^{n-mam}_{image}), ROTATE to 90º, 180º,and 270º;
    Till all images had been re-aligned;
    Perform FLIP on all aligned images;
    Write all images in as subsampled images;
    Repeat on other training data;
end;
```

After applying rotation operations, the flipping operation is performed, and the resultant images undergo the filtering process (i.e. forming the convolution layers using kernels). The forming of convolution layers requires passing the filter over all of the pixels of images. The values of the cells of the matrix filter represent the weights of the CNN. The new values that form the convolution layers are computed based on the sums of the multiplication in the CNN. This contributes to solving the shift problem because the first few pixels (that form the boundary) in the input image are manipulated by the filters based on a padding process. Fig. 12 illustrates the idea behind solving the shift problem.

Solving shift problem. In Fig. 12, the region of shifting (RoS) is constructed by the padding process. This in turn gives space to shift the image in the four directions without any resultant distortion in terms of math. That is because the multiplications by zero do not affect the result of the calculation (i.e. sums of the multiplications). However, the RoS is limited by the size of the filter that is used. Therefore, a distortion is generated in the case exceeding the region (in Fig. 12, no more than 1-pixel shifting). When using the 5 × 5-size filter, the RoS is 2 pixels. In general, the RoS is defined in terms of the filter's size as:

$$RoS = \frac{sum\ of\ rows\ (filter) - 1}{2} \tag{6}$$

Solving the scaling problem. It is worth mentioning that (C) in Fig. 13 illustrates the key idea behind the solution of the scaling problem. In other words, scaling means that the intensity values of a given image may increase (referred to as scaling up or scaling with a positive "+" value), decrease (referred to as scaling down or scaling with a negative "-" value), or remain constant (which is a special case of scaling that leads to the same image without any change or scaling with a zero "0" value). Because the max function is employed in the pooling process, all values that are lower than or equal to the maximum values of each quarter of the image will be contained automatically in the output. In (C) in Fig. 13, the first quarter has increased intensity values (19 becomes 22, for example). Although this change is performed, this does not affect the output of the pooling process. This in turn leads to the scaling problem being absorbed by the max function.

D. Segmentation

The objective of this step is to identify the edges as well as the features included within the edges (i.e. the pooled features extracted from the previous step). To this end, the Gaussian mixture model (GMM) is used. The GMM is a weighted sum of k component Gaussian densities. Formally, it is represented by:

$$p(x|\delta) \sum_{r=1}^{k} \omega_r \, g(x|\beta_r.\Sigma_r) \tag{7}$$

where x is a D-dimensional continuous-valued data vector (i.e., measurements or features), ω_r, *r =1, 2, …, k* are the mixture weights, and $g(x|\beta_r.\Sigma_r)$, *r =1, 2, …, k* are the component Gaussian densities. Each component density is a D-variate Gaussian function of the form:

$$g(x|\beta_r.\Sigma_r) = \frac{1}{(2\pi)^{D/2}|\Sigma_r|^{1/2}} exp\left\{-\frac{1}{2}(x-\beta_r)' \, \Sigma_r^{-1}(x-\beta_r)\right\} \tag{8}$$

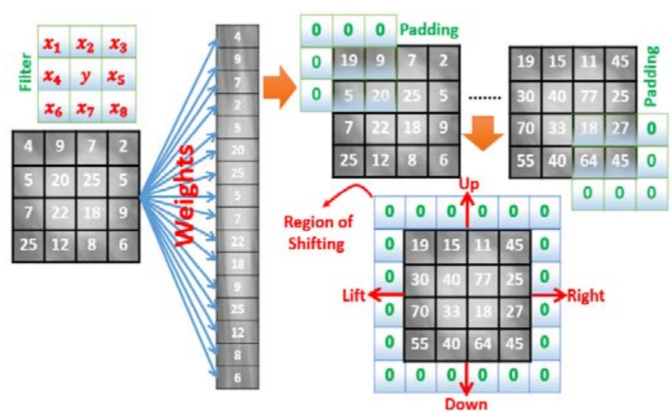


Fig. 12. Solving Shift Problem.

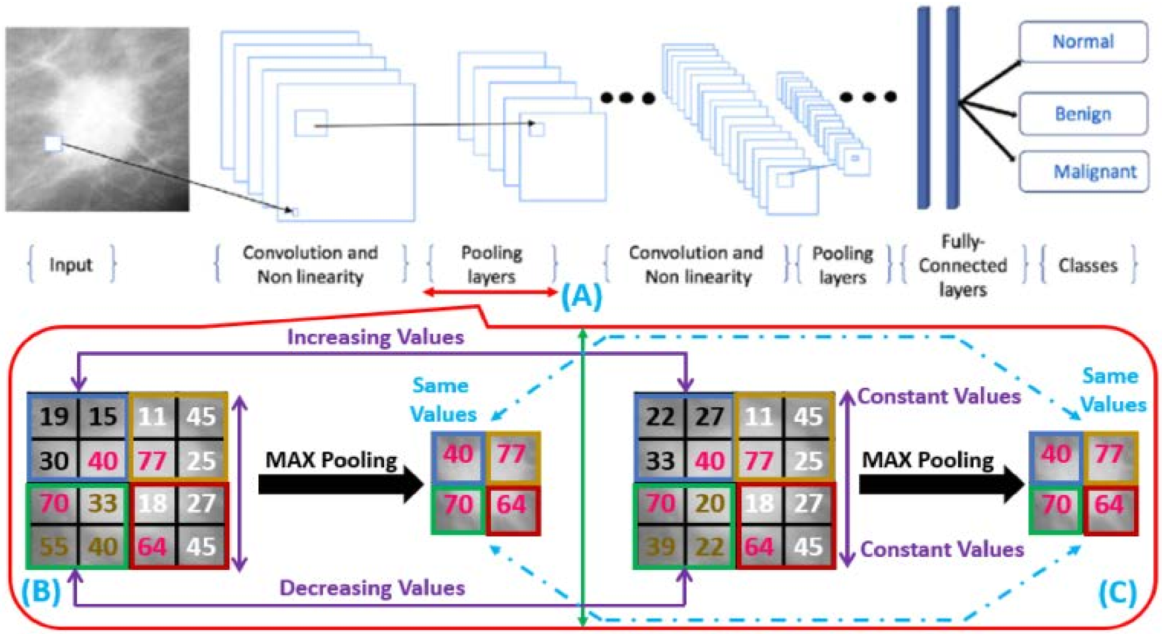


Fig. 13. Details of the Construction of the Pooling Layers. (A) Represents the General Structure of the CNN Model, where many Pooling Layers are Generated. (B) Actual Pooling Process based on the Max Function, where the Highest Values of Intensities are Selected to form Pooling Layers (40, 77, 70, and 64 are the Highest Values that Correspond to the Four Quarters of the Intensity Matrix). (C) Illustrates the Three main Options that may Occur During the Manipulation (Increasing Values of Some Intensities, Decreasing Values of Some Intensities, and Remaining Constant). In Spite of the Three Options Occurring at the Same Time, the Output is the Same (i.e. 40, 77, 70, and 64).

with mean vector β_r and covariance matrix Σ_r. The mixture weights satisfy the constraint that $\sum_{r=1}^{k} \omega_r = 1$. The complete Gaussian mixture model is parameterized by the mean vectors, covariance matrices and mixture weights from all component densities [48]. These parameters are collectively represented by the notation:

$$\delta = \{\omega_r , \beta_r , \Sigma_r\} \, |r = 1.2. \ldots . k \quad (9)$$

Visually, the output of the GMM for a pre-processed mammogram image is shown in Fig. 14.

E. Classification

This step is the final one in the prediction process. The objective of this step is to show the output of the classifier (T/S CNN). The output of the classifier is one of the three classes, which are normal, benign, and malignant. From a numerical point of view, a mathematical function is required to perform the prediction process. In this context, the softmax function is used for multi-classification. Generally, it is often used in neural networks to map the non-normalized output to a probability distribution over predicted output classes [49].

The softmax function normalizes the outputs of each neuron such that each numerical value will be between 0 and 1. Due to the normalization process, each output is divided into parts that meet the following criteria (the total sum of the outputs is equal to 1). Formally, the softmax function is given by:

$$\partial(VoI)_\tau = \frac{e^{VoI_\tau}}{\sum_{\sigma=1}^{\sigma} e^{VoI_\sigma}} \quad (10)$$

where VoI defines a vector of the inputs to the output layer. If there are 10 output units, then there are 10 elements in VoI. τ indexes the output units, so that $\tau = 1.2 \ldots . \sigma$ [48].

Fig. 15 visually illustrates the three main output classes in this work.

It is obvious that, in Fig. 15, if the ∂ value is 0.11, this means that the input mammogram image has a malignant mass. If the ∂ value is 0.85, the input mammogram image has a benign mass. If the ∂ value is 0.04, this means that the input mammogram image is normal.

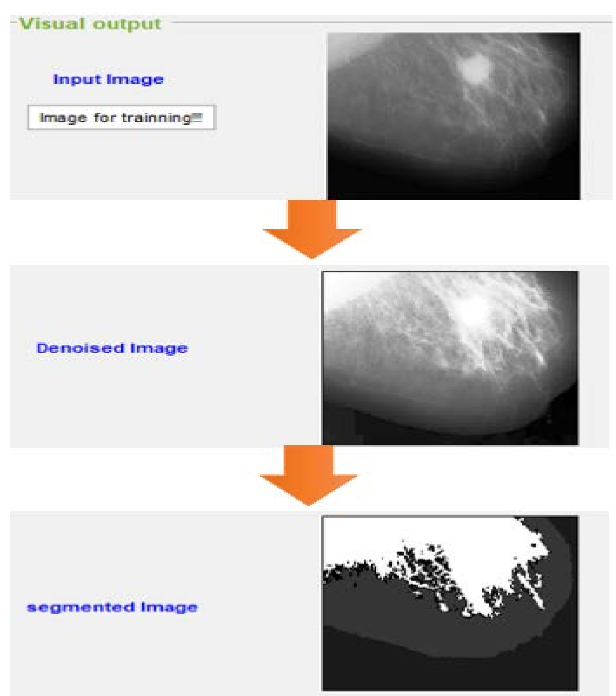


Fig. 14. Output of the Segmentation Step (Applying the GMM Filter).

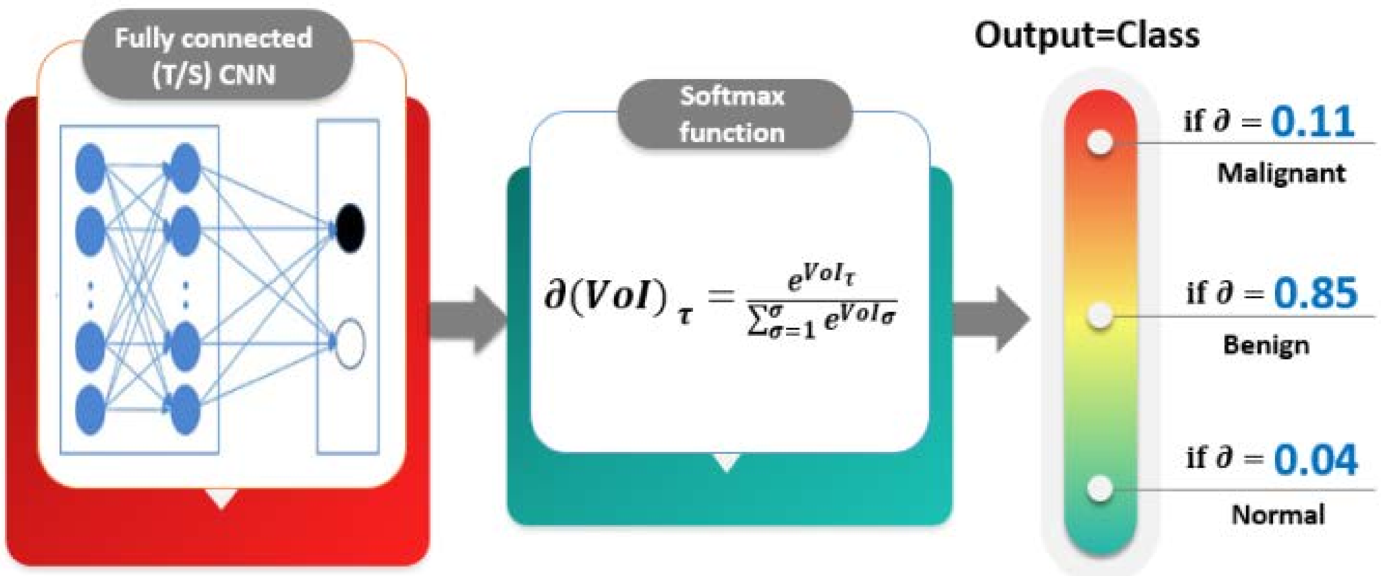


Fig. 15. Output Classes of the Prediction Process in the T/S CNN from a Numerical Perspective.

IV. USED METRICS

Three types of metrics are presented for use in the evaluation process. They are AI-based metrics, performance-based metrics, and quality of image metrics.

A. AI-based Metrics

In general, the confusion matrix (CoMa) is an effective benchmark for analyzing how well a classifier can recognize the images of different classes. The CoMa is formed considering the following terms [50]:

1) True positives (TP): positive images that are correctly labelled by the classifier.

2) True negatives (TN): negative images that are correctly labelled by the classifier.

3) False positives (FP): negative images that are incorrectly labelled as positive.

4) False negatives (FN): positive images that are mislabeled as negative.

Table III shows the CoMa in terms of the TP, FN, FP, and TN.

Relying on the CoMa, the accuracy (Acc), sensitivity (Sen), specificity (Spe), precision (Pre), and recall (Rec) metrics are driven. For a given classifier, the accuracy can be calculated by considering the recognition rate, which is the percentage of the test set images that are correctly classified. The accuracy is defined as:

$$Acc = \frac{(TP+TN)}{number\ of\ all\ records} \quad (11)$$

Accuracy-based evaluation. In this context, a higher accuracy corresponds to a better classifier output. The maximum value of the accuracy metric is 1 (or 100%), which is achieved when the classifier classifies the images correctly without any error in the classification process.

Sensitivity refers to the true positive recognition rate. It is given by:

$$Sen = \frac{TP}{P} \quad (12)$$

Sensitivity-based evaluation. In this context, a higher sensitivity corresponds to a better classifier output. The maximum value of the sensitivity metric is 1 (or 100%), which is achieved when the proportion of true positive cases equals the number of P cases.

For specificity, it refers to the true negative recognition rate. It is given by:

$$Spe = \frac{TN}{N} \quad (13)$$

Specificity-based evaluation. In this context, a higher specificity corresponds to a better classifier output. The maximum value of the specificity metric is 1 (or 100%), which is achieved when the proportion of true negative cases equals the number of N cases.

For precision, it refers to the exactness (what % of tuples that the classifier labelled as positive that are actually positive). It is given by:

$$Pre = \frac{TP}{TP+FP} \quad (14)$$

TABLE III. CONFUSION MATRIX

Actual class (Predicted class)	**Confusion matrix**		
	C1	***¬ C1***	***total***
C1	True Positives (TP)	False Negatives (FN)	TP + FN = P
¬ C1	False Positives (FP)	True Negatives (TN)	FP + TN = N

Precision-based evaluation. In this context, a higher precision corresponds to a better classifier output. The maximum value of the precision metric is 1 (or 100%), which is achieved when FP=0.

Recall refers to the completeness (what % of positive tuples did the classifier label as positive?). It is given by:

$$Rec = \frac{TP}{TP+FN} \tag{15}$$

Recall-based evaluation. In this context, a higher recall corresponds to a better classifier output. The maximum value of the recall metric is 1 (or 100%), which is achieved when FN=0.

ROC curves are used to enable the visual comparison of different classification models. These curves indicate the balance between the true and false positive rates, and the area under the ROC curve denotes the accuracy of the classifier [47].

ROC-based evaluation. In this context, a model representing a line closer to the diagonal line (i.e. the closer the area is to 0.5) is a less accurate model.

B. Performance-based Metrics

Time of response (ToR) is used to evaluate approaches in terms of performance. The ToR is calculated based on the total time of the four main steps that are illustrated in Fig. 6 above (i.e. pre-processing, feature extraction, segmentation, and classification steps). ToR is given as:

$$ToR = T_{pre} + T_{fext} + T_{seg} + T_{clas} \tag{16}$$

Where $T_{pre}.T_{fext}.T_{seg}.and\ T_{clas}$ denote the time consumed by the pre-processing, feature extraction, segmentation, and classification steps, respectively.

It is worth mentioning that, the shorter the ToR is, the better the performance of the approach is.

C. Quality of Image Metrics

Here, we employ the mean square error (*MSE*) and peak signal-to-noise ratio (*PSNR*) metrics. These metrics provides numerical values to measure the amount of distortion. The PSNR measures the percentage of the signal to the noise. If its value is high, the quality of the image is good. It is given by:

$$PSNR = 20\ log_{10}\left(\frac{max_i}{\sqrt{MSE}}\right) \tag{17}$$

Where the MSE is given by:

$$MSE = \frac{1}{m^2}\sum_{i=1}^{m}\sum_{j=1}^{m}\left\|img_{prep}^{after} - img_{prep}^{before}\right\|^2 \tag{18}$$

Where img_{prep}^{after} and img_{prep}^{before} denote the mammogram images after the pre-processing step and before the pre-processing step, respectively. It is worth mentioning that there is an inverse mathematical relationship between the MSE and PSNR metrics.

V. Experimental Results and Evaluations

This section is arranged so that first it first presents the setup and the approaches that are intended to be compared. Then, the actual results and the corresponding discussions are provided.

A. Setup

The proposed AI-based system is implemented on a laptop that has the specifications organized in Table IV.

We selected two approaches to compare with the proposed approaches. They are arranged in Table V.

Since refs [7] and [11] are based on RF and KNN, we present a brief overview of these techniques, as described below.

The RF algorithm, or forest of decision trees, is a classification algorithm that reduces the variance of forecasts from a decision tree alone, thereby improving their performance. For this, it combines many decision trees in a bagging-type approach.

The RF algorithm performs parallel learning on multiple decision trees constructed randomly and trained on different subsets of data. The ideal number of trees, which can go up to several hundred or more, is an important parameter; it is very variable and depends on the problem. Concretely, each tree in the random forest is trained on a random subset of data according to the bagging principle, with a random subset of features according to the principle of random projections. Predictions are then averaged when the data are quantitative or used for a vote on qualitative data, in the case of classification trees. The random forest algorithm is known to be one of the most efficient classifiers. Fig. 16 shows the basic concept of the RF technique.

The KNN algorithm is an unsupervised machine learning algorithm that can be used to solve both classification and regression problems. The KNN algorithm does not require a learning phase; it is just necessary to store the set of learning data.

TABLE IV. SPECIFICATIONS

Item	**Details (value)**
Operating system	Microsoft Windows 10 Home
System type	x64-based PC
System model	HP Laptop 15-bs0xx
Processor	Intel(R) Core(TM) i5-7200U CPU @ 2.50 GHz
RAM	4 GB
Display chip type	Intel(R) HD Graphics Family

TABLE V. SELECTED APPROACHES

Ref	**Selected Approaches**		
	Used technique	***Journal***	***Year***
[7]	RF-based	Journal of medical systems	2016
[11]	KNN-based	IEEE	2013

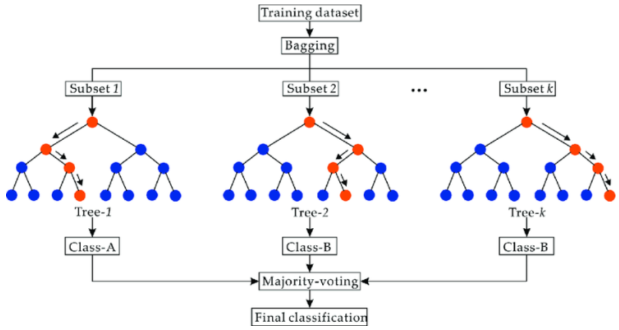


Fig. 16. RF Technique Concept.

Let E be a set containing n labeled data: $E = \{(y_i . x_i)\}$ with $1 < i < n$, where y_i corresponds to the class (label) of the data i and where the vector x_i of dimension p ($x_i = (x_{i1}.x_{i2}. \dots .x_{ip})$) represents the predictor variables of the data i.

Consider a data u that does not belong to E and that does not have a label (u is only characterized by a vector x_u of dimension p).

Let d be a function that returns the distance between the data um and any data um belonging to E. Let an integer k be less than or equal to n. Below are the general steps of the KNN algorithm:

1) Calculate the distances between the data u and each data belonging to E using the function d.

2) Retain the k data from the data set E closest to u.

3) Attribute to u the class that is most frequent among the k closest data.

Fig. 17 illustrates the concept of the KNN technique.

B. Results and Discussion

1) Results without the effects of shift and scaling problems: In the context of these experiments, 200 mammogram images are used. Since the AI-based metrics are inspired from the CoMa, the values of the cells that form the CoMa are needed. Table VI shows the values of the CoMa elements.

Based on the metrics that are derived from the AI, Table VII presents the values of the metrics along with the comparison with the RF-based and KNN-based approaches.

AI-based metric discussion. The proposed SCNN approach achieves the best values. The reason is that the mammogram images are scanned perfectly by the kernels/filters to extract features and then form the entire image feature map. The pre-processing step that includes HisE followed by AMF contributes to enhancement of the values of all of the metrics. That is because the contrast and the details of the input images are enhanced, which in turn leads to better training (i.e. training on very clear images). As a result, the accuracy level is high. This justification can be used to explain all of the high values of the rest of the metrics. The TCNN is ranked second. The reason is that it uses only the HisE method in the pre-processing step. This leads to lowering the values of the metrics slightly. Compared to the SCNN and TCNN approaches, the RF performs poorer, but it performs better when compared to the KNN approach. This can be justified by the nature of the RF approach, which takes into consideration all of the possible options that may be generated in the decision trees while processing the images to make the final decision (i.e. classifying the mammogram input image).

Fig. 18 illustrates the ROC-based comparison among the four approaches.

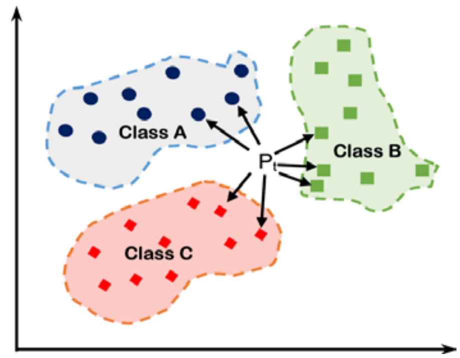


Fig. 17. KNN Technique Concept.

TABLE VI. VALUES OF COMA ELEMENTS

200 images 131 (P) 69 (N)	Values Of CoMa Elements			
	TP	***TN***	***FP***	***FN***
RF	102	54	29	15
KNN	99	50	32	19
TCNN	119	65	12	4
SCNN	124	66	7	3

TABLE VII. AI-BASED METRIC VALUES

Approach	**Metric**			
	Acc	***Sen***	***Spe***	***Pre***
KNN	74%	84%	61%	76%
RF	78%	87%	65%	78%
TCNN	92%	97%	84%	91%
SCNN	95%	98%	90%	95%

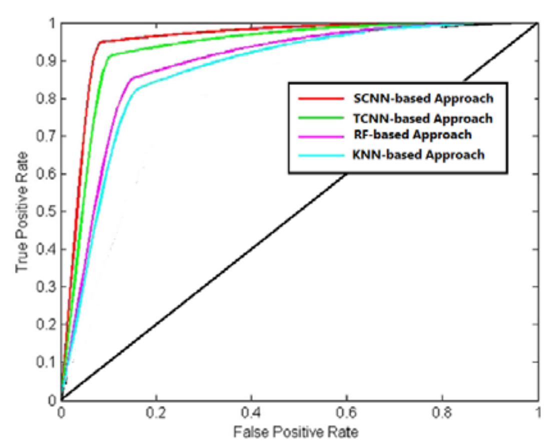


Fig. 18. ROC Curves.

ROC-based discussion. The results obtained from the AI-based metrics are supported by the ROC curves. This is reflected through the area under the ROC, where the SCNN approach has the highest area. The TCNN approach comes in next due to the same reasons presented under the discussion of the AI-based metrics. Again, the RF approach performs better than the KNN approach.

Performance-based metric discussion. Fig. 19 illustrates the comparison according to the response time. In terms of time, the SCNN approach comes in at the bottom (i.e. performs the worst), followed by the TCNN approach. The KNN approach comes in at the top, and the RF approach is ranked second. The reason behind the previous order is related to the intensity of the operations used in each step involved in the prediction process (i.e. from the pre-processing step to the classification step). Because the CNN is included in both the proposed TCNN and SCNN approaches, the operations that are involved (constructing the convolution and pooling layers), as well as using extra methods for pre-processing, consume more time. This in turn leads to a long ToR metric value. As for the KNN approach, it directly manipulates the input mammogram images and provides the prediction without any additional delays, which leads to the shortest ToR metric value.

Quality of image-based discussion. From an image processing point of view, the greater the clarity of the image is, the more accurate the output is. This plays a critical role in the medical field due to the sensitivity of diagnosis based on image processing. Since we used HisE and AMF in the pre-processing step, we examine the four options that are generated from them. Table VIII summarizes the values of the MSE and PSNR metrics.

Applying HisE followed by AMF yields the lowest MSE and the highest PSNR, which means that this option is the best for generating the clearest mammogram images (actually, this option is the one used in this work). The reason is that the HisE enhances the details of the mammogram input image. These details undergo another optimization related to surrounding the details within edges, including the area of the cancerous mass. In other words, double enhancement is applied on the mammogram images, leading to a good isolation of the cancerous mass, and this is the root reason behind the higher accuracy of classification as mentioned previously. In contrast, when applying the AMF followed by the HisE, the MSE yields a higher error rate, and the PSNR yields lower clarity of the output processed image. That is because identifying the location of cancerous mass within the mammogram image first leads to the inclusion of details that may be out of interest. Thus, when applying the HisE on the image, the details will affect the accuracy of the classification process because the unwanted details are seen as noise. It is obvious that applying only AMF or HisE generates poor-quality images compared to the other options.

2) Results taking into consideration the effect of shift and scaling problems: In the context of this part of the experiments, we manually add some noise to the mammogram breast images to generate the shift and scaling problems. Then, robustness against the shift and scaling problems is measured based on repeating the same scenario (calculating the values of the AI-based metrics, performance metrics, and quality of image metrics) presented in the first part of the experiments.

Fig. 20 illustrates an output image, as a sample, after adding shift and scaling problems.

The values of the elements of the CoMa are arranged in Table IX.

Table X shows the values of the AI-based metrics.

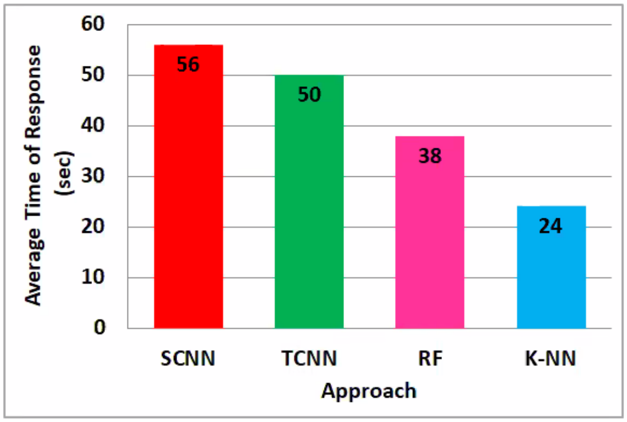


Fig. 19. Performances of Approaches.

TABLE VIII. VALUES OF MSE AND PSNR METRICS

Filter	Metric	
	MSE	***PSNR***
HisE	28.96769	13.493
AMF	32.6703	13.1818
HisE+AMF	12.80	25.98
AMF+HisE	15.72638	20.2516

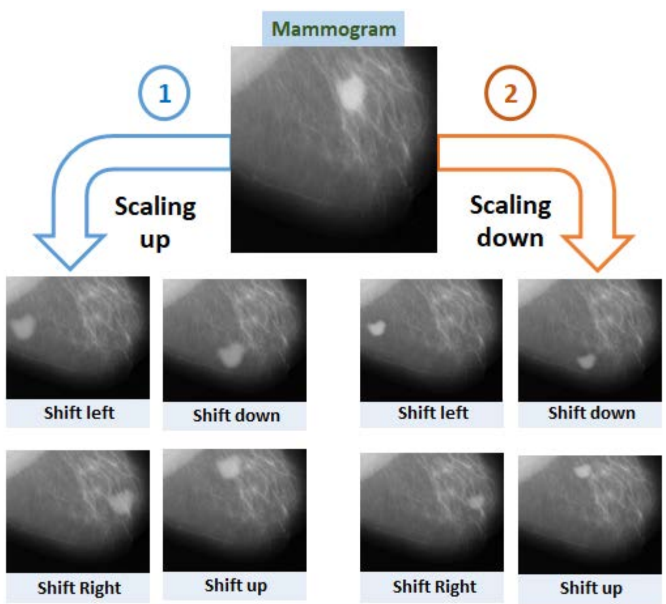


Fig. 20. Output Mammogram Image after Adding Shift and Scaling Problems.

TABLE IX. VALUES OF THE CoMA'S ELEMENTS AFTER APPLYING SHIFT AND SCALING PROBLEMS

200 images 131 (P) 69 (N)	**Values of CoMa Elements**			
	TP	***TN***	***FP***	***FN***
RF	91	49	40	29
KNN	85	45	46	24
TCNN	116	61	15	8
SCNN	122	63	9	6

TABLE X. VALUES OF AI-BASED METRICS AFTER APPLYING SHIFT AND SCALING PROBLEMS

Approach	**Metric**			
	Acc	***Sen***	***Spe***	***Pre***
KNN	65%	78%	49%	65%
RF	70%	76%	55%	69%
TCNN	89%	94%	80%	89%
SCNN	93%	95%	88%	93%

AI-based metrics discussion. In general, the shift and scaling problems have a negative impact on all of the AI-based metrics for all of the approaches. However, the SCNN approach shows the highest resistance against these problems. That is because of the support it offers via a strong pre-processing step, which has the ability to remove noise. On the other hand, the padding operation used to form the convolution layers and the max function used to construct the pooling layers contribute to limiting the negative impact of the shift and scaling problems. In numbers, the accuracy of the SCNN approach decreases from 95% to 93% after applying the shift and scaling problems. The TCNN approach comes in next in terms of resistance against the problems, with its accuracy decreasing from 92% to 89%. Here, the use of only HisE to remove the noise is the reason the accuracy of the TCNN is lower than the accuracy of the SCNN. For the KNN and RF approaches, there is a significant decrease in the accuracy value, from 74% to 65% and from 78% to 70%, respectively.

Fig. 21 shows the performance of the four approaches involved in the comparison.

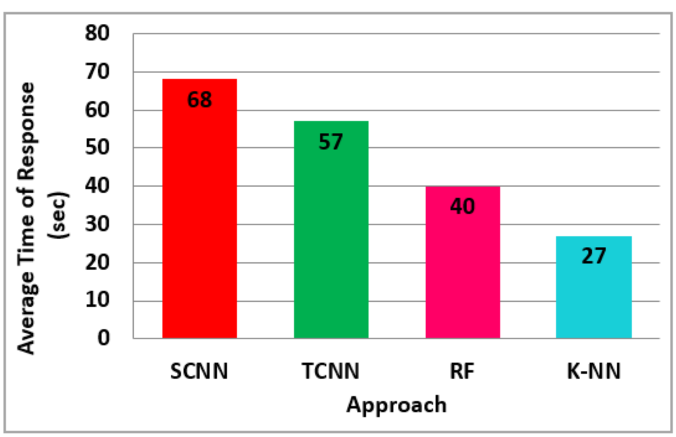


Fig. 21. Performances of the Approaches after Applying the Shift and Scaling Problems.

Performance-based metric discussion. In general, the value of the ToR metric shows poor performance due to the additional processing to remove the noise that is added by the shift and scaling problems. However, the order of the approaches in terms of performance did not change after applying the shift and scaling problems (when compared to the first scenario). It is noticed that the TCNN and SCNN approaches experienced higher rates of increase compared to the KNN and RF approaches. This is normal because the pre-processing step needs more time to generate clear output images.

Table XI summarizes the results of the quality of image metrics after applying shift and scaling problems.

TABLE XI. VALUES OF QUALITY OF IMAGE METRICS UNDER IMPACT OF THE SHIFT AND SCALING PROBLEMS

Filter	**Metric**	
	MSE	***PSNR***
HisE	30.75	12.44
AMF	35.82	12.24
HisE+AMF	14.79	22.30
AMF+HisE	18.54	17.23

Quality of image-based discussion. In general, the quality of the mammogram input images is negatively affected by the shift and scaling problems. This is reflected in the value of the MSE metric (it shows increasing values) and the PSNR metric (it shows decreasing values). However, the approach that depends on the HisE method followed by the AMF method has the best values. That is because of the effectiveness of employing the histogram equalization and the adaptive filter to remove noise generated by the shift and scaling problems. As for the rest of the approaches in Table XI, they suffer from the two problems, which means a lower resistance against the noise. In terms of ranking, the approach that relies on the AMF method followed by the HisE method comes in second, followed by the HisE and AMF approach.

VI. CONCLUSION

Diagnosis in the medical field plays an important role in saving the lives of patients. This is highlighted specially in the cases where early detection of illness is required, such as breast cancer. Employing machine learning to perform diagnosis on behalf of physicians makes the accuracy of diagnosis a critical issue. That is because low accuracy in diagnosis (i.e. mistakes) sometimes leads to death. The accuracy level is also tightly coupled with blurring of the processed images in the medical field. This leads to the following research questions: (1) How can the accuracy of the artificial systems be enhanced? (2) How can the noise that is generated by the shift problem included in the images be manipulated before being processed by machines before training? (3) How can the noise generated by the scaling problem of the images be addressed before entering the training phase? This work presents the TCNN and SCNN approaches, which respond to the blurring issue. The TCNN and SCNN exploit the mechanism of the neural networks used to construct the convolution layers to deal with the shift problem. Specifically, the padding operation is exploited during the scanning of the input mammogram images by filters. To manipulate the scaling problem, the TCNN and SCNN also exploit the mechanism of the neural networks used to construct the pooling layers. Specifically, this is done by depending on the max function to generate the feature map of the mammogram images. As for enhancing the accuracy level, the FRbA is proposed. The key idea is to generate different instances of the cancerous mass from the input mammogram images to generate more features. Specifically, this is done by relying on both the flipping and rotation mathematical operations that can be applied on the mammogram images. The proposed CNN and SCNN approaches are trained and tested using the MIAS dataset available online, where 200 mammogram breast images are utilized. The proposed CNN and SCNN approaches are evaluated under different confusion matrix-based matrices and compared with similar approaches. The SCNN and TCNN achieved accuracies of 95% and 92%, respectively, while the RF-based and KNN-based approaches exhibited accuracies of 78% and 74%. In terms of applicability, the results of the accuracy related to both the TCNN and the SCNN make them promising approaches to be used in medical sector.

For limitations, due to the high level of both the privacy and the security in medical sector, the implementation of the proposed approaches did not perform on real medical data. In addition, response time did not take into consideration in this work.

In future work, we intend to implement the proposed approaches with a real medical dataset. In addition, enhancing performance in terms of response time will be taken into consideration by implementing the proposed approaches on Hadoop.

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A Dynamic Two-Layers MI and Clustering-based Ensemble Feature Selection for Multi-Labels Text Classification

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***Abstract*—Multi-label text classification deals with the issue that arises from each sample being related to multiple labels. The text data suffers from high dimensionality. In order to resolve this issue, a feature selection (FS) method can be implemented for efficiently removing the noisy, irrelevant, and redundant features. Multi-label FS is a powerful tool for solving the high-dimension problem. With regards to handling correlation and high dimensionality problems in multi-label text classification, this paper investigates the various heterogeneous FS ensemble schemes. In addition, this paper proposes an enhanced FS method called dynamic multi-label two-layers MI and clustering-based ensemble feature selection algorithm (DMMC-EFS). The proposed method considers the: 1) dynamic global weight of feature, 2) heterogeneous ensemble, and 3) maximum dependency and relevancy and minimum redundancy of features. This method aims to overcome the high dimensionality of multi-label datasets and acquire improved multi-label text classification. We have conducted experiments based on three benchmark datasets: Reuters-21578, Bibtex, and Enron. The experimental results show that DMMC-EFS has significantly outperformed other state-of-the-art conventional and ensemble multi-label FS methods.**

Keywords—Multi-label text classification; high dimensionality; filtering method; ensemble clustering; ensemble MI feature selection

I. Introduction

In multi-label text classification, each sample is related to one or more classes at the same time. The difference between main key to a multi-label learning and single label learning is that the labels in the multi-label learning are related and inclusive. Thus, the problems related to multi-label learning are more challenging to solve. In the field of machine learning and data mining, multi-label learning is an endeavor task that greatly suffers from high dimensionality [1] [2].

The limitation of this research in multi-label text learning process, there is a significant number of irrelevant, redundant, and disruptive information. The number of involved features is usually large. The high dimensionality of multi-label text data results in challenges such as poor performance, over-fitting, and anything from computational to classification complexity. Some existing multi-label feature selection (FS) methods can be considered in order to minimize the effect of the irrelevant and redundant features that disrupts the learning process [3]. A label or a class can be a non-convex region which is a union of several overlapping or disjointed sub-regions. As a result, they may suffer from large memory requirements or poor performance. FS is a method that aims to discover a minor subset of features that can define the original features of the dataset or something better [4] [5], and it can be regarded as an effective way to manage the problem of high dimensionality. FS can reduce the dimensionality of the original data by speeding up the learning process and building comprehensible learning models with quality generalization performance. In multi-label learning, there is a need to implement multi-label feature reduction techniques so that they remove any irrelevant features and transform high dimensional documents into low dimensional ones. Many algorithms exist that can simplify the multi-label FS sets, but they neglect the interrelations among multi-label FS sets. However, multi-label filter-based FS algorithms consider the label interactions and are able to promptly and effectively select features [1] [6] by evaluating the measures. Several researches [7] [8] [9] [10], have proposed the adaption of single-label FS techniques.

The multi-label FS algorithms are designed based on the decomposition of multi-label learning into a number of single-label classification, and thus, they ignore the correlation between the different labels. By reviewing the existing studies, it can be assumed that the single-label filter-based FS methods are not appropriate for multi-label datasets. Therefore, after taking several factors into consideration, it seems reasonable to propose:

The first priority of the FS method should be to maximize the feature-class dependency and minimize the feature-feature conditional redundancy. FS methods help reduce the redundant dimensions without suffering the loss of the total information. These redundant features [11] [12] [13] provide overlapped information about the selected feature.

Secondly, a good ensemble FS method should take into account the functional diversity of the data. In other words, the ensemble FS method should reduce the possibility of overvoting caused by the other existing FS methods [14].

*Corresponding Author

Thirdly, the FS method [15] should consider the dynamic changes of the selected features along with the class and dynamic global weight of the feature.

Therefore, the following are the expected key contributions of this paper:

1) Investigating the several state-of-the-art conventional multi-label FS methods that have been derived from different mathematical and statistical concepts for generating different FS solutions. The aim is to identify and select the best multi-label FS methods that can be used in the ensemble FS method. The expected outcome of this endeavor is to identify features that are effective in accomplishing the intended tasks.

2) Proposing two multi-label ensemble FS methods: multi-label Mean ensemble FS method and multi-label Plurality Vote ensemble FS method.

3) Designing a new dynamic multi-label MI and clustering-based ensemble FS method that considers the functional diversity and dynamic changes of the selected features along with the class and dynamic global weight of the feature.

Thus, this paper is presented in several sections where Section II briefly reviews the related work; Section III briefly describes the FS methods that have been used in this study; Section IV explains the framework of our proposed multi-label ensemble FS method that solves the problem of multi-label high-dimensionality in multi-label text classification; Section V presents the classifier models used in the experiments; Section VI presents the experimental work; Section VII presents the experiment results; The results discussion is presented in Section VIII; and lastly, Section IX concludes the paper.

II. Related Work

In multi-label text classification, the goal of an FS method is to reduce the feature space dimensions and improve the classification efficiency and performance by removing redundant and irrelevant (disruptive) features. In multi-label text classification, there is a need for a method that ensures multi-label feature reduction by subtracting the irrelevant features and transforming high dimensional documents into low dimensional ones. Many existing algorithms simplify the multi-label FS sets but neglect the interrelations among the features of multi-label data sets. Multi-label filter-based FS methods consider label interactions and promptly and effectively selects features based on evaluating measures [3].

In [16], proposed an ensemble filter-based FS technique for multi-label data classification. As suggested in [16], ensemble FS provides relatively stable feature ranking and reduces the negative effects of the change in the training dataset. This technique combines the results of four FS methods in order to create an ensemble method. In [17], proposed an ensemble method that employs a prediction risk and forward search strategy for creating an ensemble FS method. They were used to evaluate the importance of selection of the features in order to generate a feature subset that can be employed to improve the classifier's performance. In [18], incorporated a mutual information measure in an ensemble method in order to create an optimal subset of features. The approach combines multiple algorithms, such as Info Gain, Gain-ratio, Relief, Chi-square and Symmetric Uncertainty. In [19], an ensemble method multi-label FS algorithm based on information entropy (EMFSIE) was proposed. The core idea of this method is to accomplish information gain for evaluating the correlation between the feature and the label set and more effectively filtering out the irrelevant features. In [20], proposed an improved global FS scheme (IGFSS) on an ensemble method that combines the superior functionality of a filter-based global FS method and a one-sided local FS method. The idea behind IGFSS is to allow the feature set almost equally represent each class in the dataset. In [11], presented a new FS method that is based on term frequency reordering of document-level (TRDL). The TRDL uses the document's frequency to measure the unbalanced factors in the data set and considers the effect of the term "frequency" on the ordering the importance of the features. Author in [21] also proposed a new text FS method based on the mutual information using sample variance (MIUSV). MIUSV is a typical variation in terms of distribution and also calculates the mutual information score of the term. In [10] proposed a fast-multi-label FS method, which is called MLFR that implements an information-theoretic feature ranking. The method in [10] speeds up the search process by scrapping the dispensable calculations and identifying the important label combinations for accomplishing a fast-multi-label FS. The method demonstrates the relationship between the labels and the features using a graphical scheme. The proposed method of [10] was used to solve a problem with datasets that contain discrete values, as it used a Symmetric Uncertainty criterion for evaluating the features. In addition, by reviewing the proposed methods in [22] [23], it can be stated that both methods used an adaptation entropy calculation in order to calculate information gain for each feature in the multi-label dataset. The features were then selected based on the resultant top scores. An FS method, which was proposed in [24]. [24], was based on information gain. The proposed methods identifies the relationship between the features and the labels in order to discover the importance of each feature in the multi-label dataset.

Based on the conclusions provided by [16] [17] [18], it was found that the FS ensemble methods provide promising results for solving the high dimensionality problem in multi-label text classification. It is crucial to further investigate the use of the ensemble filter-based method in different applications, such as using it for multi-label FS methods wherein the results are expected to be higher.

This work examines the various heterogeneous FS ensemble schemes and proposes a dynamic multi-label two layers MI and clustering-based ensemble feature selection algorithm (DMMC-EFS). The proposed method takes the following factors into account: 1) dynamic global weight of the feature; 2) heterogeneous ensemble; 3) maximum dependency and relevancy and minimum redundancy of the features. In the following section (Section 3), we will discuss the various FS ensemble methods before we venture into explaining in detail our proposed method on multi-label FS (Section 4).

III. Multi-Label FS Ensemble Methods

FS is an important for ensuring the attainment of an effective multi-label text classification system. Adapting an FS method improves the performance of text classification tasks in terms of their learning speed and effectiveness. An FS method also reduces the number of data dimensions and removes any irrelevant, redundant, and disruptive data. FS methods can be effective to solve the classification problem of multi-label datasets. They can improve the performance of the tasks and even speed up the process. They can remove the irrelevant, noisy, and redundant data. Several approaches, including filter methods and wrapper methods, have been considered in order to perform FS for multi-label learning. The filter-based FS methods do not take into account features redundancy and feature class dependency, and their results are inconsistent with the available classifiers. On the other hand, the wrapper methods usually produce better results, but their drawback includes the risk of overfitting and high computational complexity. The ensemble methods [25] are also popular methods for FS in case of high dimensional datasets. However, the redundancy of the features among themselves and all the class labels is not considered by the existing ensemble-based FS methods.

In order to design an effective multi-label FS method so that it can remove the irrelevant features and handle the high dimensionality problem, it should be able to ensure minimum redundancy among the selected features and have maximum dependency between features and all the class labels [18] [26] [27] [28] [19] [1] [29] [6]. In addition, the multi-label FS method should scalable, not computationally demanding, and be as fast as the filtering methods, and they should perform well like the wrapper methods.

In order to handle the correlation and high dimensionality problems in multi-label text classification, this work investigates the various heterogeneous FS ensemble schemes and proposes an FS method (DMMC-EFS). The baseline FS method and multi-label FS method is described in Section 3.1 and Section 3.2, respectively.

A. Baseline Feature Selection Method

Several FS methods have been analyzed in order to select features from each sample, including Information Gain, F-score, Relief, mutual information, and normalized mutual information. Based on the existing literature review [27] [28] [19] [6] [30], these methods and their extensions prove to be effective in case of multi-label FS, and in addition, they are able to cope with the feature-label correlation [1].

1) Information Gain (IG): IG is an FS algorithm [31] [32] that is used to measure the quality of the features in solving the machine learning problem. The appearance or absence of a feature is measured in order to what extent it contributes to the attainment of a correct classification result. IG is one of the most popular and commonly used FS in the multi-label text classification system. It is formally defined by using the following equation:

$$IG(x,y) = -\sum_{i=1}^{n}\sum_{j=1}^{n} p\big(x(i),y(j)\big)\, log\big(x(i)\big) \qquad (1)$$

Here, $p\big(x(i)\big)$ indicates the likelihood of feature x, and $p\big(x(i),y(j)\big)$ is the joint likelihood when $\big(x(i),y(j)\big)$ is denoted simultaneously.

2) F-score: F-score is a multi-label FS method [3] that evaluates the discriminative ability of the features. F-score estimates the relevance of the features based on their ability to discriminate between the groups of the target variable and discrimination within each group. A higher F-score indicates an increased likelihood that this feature is discriminative. It is formally defined through the following equation:

$$F - score_i = \frac{\sum_{k=1}^{c}(\overline{f_i^k} - \overline{f_i})}{\sum_{k=1}^{c}\left[\left(\frac{1}{N_i^k}-1\right)\sum_{j=1}^{N_i^k}(\overline{f_{ij}^k} - \overline{f_i^k})\text{^}2\right]} \qquad (2)$$

Here, c is the number of labels, and n is the number of features; N_i^k is the number of samples of the feature i in label k, (k = 1, 2,…, c; i = 1, 2,…, n), x_{ij}^k is the j the training sample for the feature i in class k, (j = 1, 2,…, N_i^k), $\overline{f_i}$ is the mean value of feature i from all labels, and$f_i^k$is the mean of the ith feature of the samples in label k.

3) Relief: Relief is the most effective and commonly used FS [5] [30] [33], in multi-label text classification system. The Relief randomly selects instances from the training data, and then estimates the features' relevance to a class based on the closest data that can be found. It assigns a high weight to the features based on each instance's ability to differentiate between the classes [32] [30]. Relief algorithm is the only individual evaluation filter-based algorithm that is capable of detecting feature dependencies.

4) Mutual Information (MI): Relief is the most effective and commonly used FS in multi-label text classification system [27] [30].

$$\mathrm{MI}(x,y) = \sum_{i=1}^{n}\sum_{j=1}^{n} \mathrm{p}\big(x(i),y(j)\big)\, log\,\frac{\mathrm{p}(x(i),y(j))}{\mathrm{p}(x(i))\times p(y(j))} \qquad (3)$$

Here, $p\big(x(i)\big)$, is the likelihood of incidence of a feature x, and $p\big(x(i),y(j)\big)$ is the joint likelihood when, $\big(x(i),y(j)\big)$ happens simultaneously. Depending on the MI definition, the filter process is described by the following steps:

a) Compute the MI of the features.

b) Use the MI values in order to calculate the mean and their standard deviation.

c) Remove any feature that has an MI value below the value acquired by subtracting the standard deviation from the mean.

5) Normalized Pointwise Mutual Information (NPMI): The measure of the mutual information FS provides a formal way to model the mutual information between the terms and the classes [6] [34]. The mutual information MI (t, c) between the term t and the class c can be defined on the basis of the level of co-occurrence between a feature f_j and a class c_i. In this work, the normalized pointwise mutual information FS method has been adopted in order to select the features for each class according to the co-occurrence measure between a feature f_j

and a class c_i. The normalized pointwise mutual information (NPMI) between the feature and its class [34] [35] can be calculated using the following equations:

$$PMI(class = c_i,) = lin\frac{p(c_i,f_j)}{p\,(c_i).p(f_j)} \quad (4)$$

$$NPMI\big(class = c_i, f_j\big) = \frac{PMI(c_i,f_j)}{\sum_{f_k} PMI\,(c_i,f_k)} \quad (5)$$

B. Multi-Label Mean Ensemble Feature Selection Method (ME-mean)

The multi-label mean ensemble FS method [29] calculates the mean feature scores across all the FS methods and then finds the overall mean value. This value is used to create the final feature list. Let us consider n data samples, $S^1, \ldots\ldots, S^n$, base feature methods, $FS^1, \ldots\ldots, FS^n$. Here, each FS method SF^i selects a list of m features $F^i = \{f^1, \ldots\ldots, f^m\}$ from the data sample S^i. The final score or ensemble score of a feature f^j from any list of features is calculated using the following equation:

$$E_{Score(f^j)} = \frac{\sum_{i=1}^{n} SF^i_{Score}(f^j)}{n} \quad (6)$$

After calculating the ensemble mean score for each feature from all lists of features, the final list of the mean ensemble FS method containing only m features that have the highest high ensemble scores is developed.

C. Multi-Label Plurality Vote Ensemble Feature Selection Method (ME-PV)

In the plurality vote ensemble [29], each FS selects its preferred list of features. These lists are used to select the candidate features. The selected features are based on the number of times they appear in the multiple lists. Once a feature is selected from a list, it is removed from the list. This process is repeated according to the number of required candidate features [29]. It should be noted that most of the votes are not required for the selection of the candidate features. Let us consider n number of data samples $S^1, \ldots\ldots, S^n$, base feature methods, $FS^1, \ldots\ldots, FS^n$, each FS method, SF^i,selects a list of m features $F^i = \{f^1, \ldots\ldots, f^m\}$ from the data sample S^i. The final score or ensemble score of a feature f^j from a list of features can be calculated using the following equations:

$$SF^i_{Score(f^j)} = \begin{cases} 1 & if \quad f^j \in F^j \\ 0 & otherwise \end{cases} \quad (7)$$

$$E_{Score(f^j)} = \frac{\sum_{i=1}^{n} SF^i_{Score}(f^j)}{n} \quad (8)$$

IV. Dynamic Multi-Label Two-Layers MI and Clustering-Based Ensemble Feature Selection Algorithm (DMMC-EFS)

This section illustrates the proposed multi-label dimension reduction technique that takes into account the 1) dynamic global weight of a feature; 2) heterogeneous ensemble; 3) maximum dependency and relevancy and minimum redundancy of the features. After the subsets of features are produced using baseline FS methods, the dynamic ensemble multi-label FS algorithm obtains a subset of useful features by combining the outputs of each method with each method in order to enhance the performance of the multi-label classification algorithm. The following figure provides the detailed steps of the proposed dynamic multi-label two layers MI and clustering-based ensemble FS methods (DMMC-EFS) (see Fig. 1).

A. Data Partitioning

Using random sampling, the dataset is partitioned into multiple samples (based on j). The process involves randomly shuffling the instances in order to ensure that the samples, $P_1, \ldots\ldots, P_j$, in each partition are properly balanced. Each data sample contains equal or almost equal number of instances from all the classes.

B. Baseline Feature Selection Methods Step

For each data sample or partition P_j , all the FS methods, $FM_1, \ldots\ldots, FM_k$, are applied to compute the FS values depending on the raw feature values of the sample to produce its selected feature list. The selected feature lists are sorted and passed on to the next stage. Each feature lists, FS_i^j, consists of all the features from the data sample or partition P_j, using the FS method FM_i. Specifically, each primary feature subset FS_i^jconsists of the top τ k features in P_j that are selected and sorted according to the filter-based measure values FM_i.

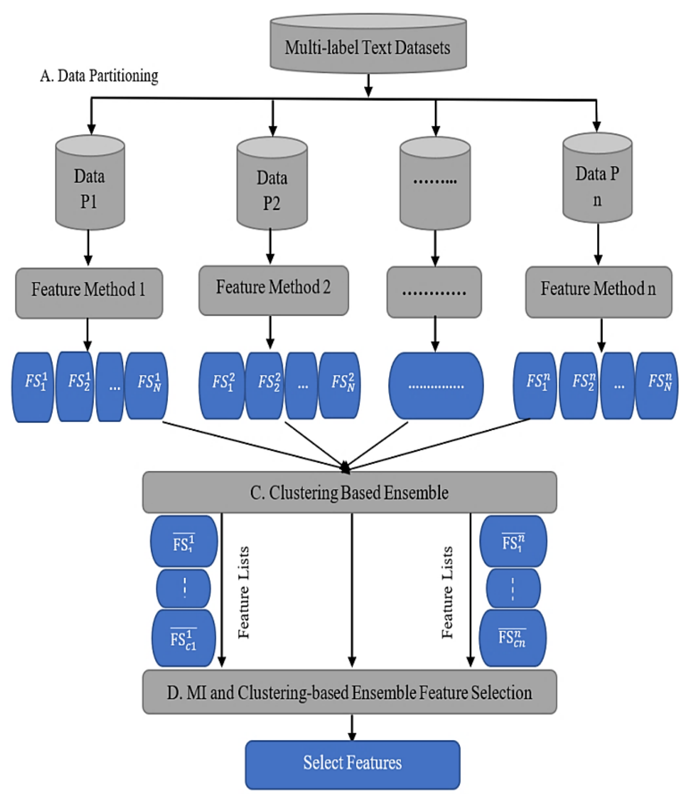


Fig. 1. The Diagram of the Proposed Dynamic Multi-Label Two Layers MI and Clustering-based Ensemble FS Methods (DMMC-EFS).

C. First Ensemble Layer (Clustering Ensemble Step)

FS methods with similar statistical and mathematical concepts may generate an alike output. If an ensemble is created by combining such similar methods, this can lead to strongly biased results. In order to avoid such bias, the FS methods that are used for an ensemble should be carefully selected. However, identifying FS methods with similar backgrounds may not be obvious, and in order to make the proposed multi-label FS ensemble more general and function well regardless of the selected baseline FS methods, we propose a graph-based clustering of group or similar ensemble intermediate FS lists that are produced using similar FS methods. With the help of the data sample or partition P_j, k intermediate feature lists are produced using the base FS methods; k intermediate feature lists are aggregated to $c < k$ feature lists, as shown in Fig. 1. The clustering step is done in order to identify and categorize the similar FS methods based on their similar outputs. Doing so should reduce the chances of allowing the similar methods to overvote the other ones, which can lead to higher diversity. The step-by-step flow of the clustering step has been summarized below:

Step1: Similarity Graph Construction: Given the data sample or partition P_j and its k intermediate feature lists that are produced by k base FS methods, $FS^j = \{\mathrm{FS}_1^j, \ldots, \mathrm{FS}_k^j\}$, each output of the FS method (a feature list) over the partition P_j is represented as a node. The edge between the two nodes, E_{xy}, is computed with each pair of intermediate feature lists $(\mathrm{FS}_x^j, \mathrm{FS}_y^j)$, where the output of two baseline FS methods x and y, with the following equation:

$$E_{xy} = \cos(\mathrm{FS}_x^j, \mathrm{FS}_y^j) = \frac{|\mathrm{FS}_x^j| * |\mathrm{FS}_y^j|}{\sqrt{(\mathrm{FS}_x^j)^2 * (\mathrm{FS}_y^j)^2}} \tag{9}$$

Step2: Node Clustering Based on Edges Weights Estimation: If their edge weight is higher than a threshold t > 0.70, two node pairs is clustered together. The threshold value is measured experimentally. The resulted feature list contains the features of both the nodes. The value of the feature f is calculated using the following equation:

$$V(f) = \begin{cases} average\ (V_x(f), V_y(f)) & if\ f\ \in \text{both } \mathrm{FS}_x^j, \mathrm{FS}_y^j \\ V_x(f) & if\ f\ \in \mathrm{FS}_x^j \\ V_y(f) & if\ f\ \in \mathrm{FS}_y^j \end{cases} \tag{10}$$

Step3: Graph Reconstruction and Node Clustering Repetition: Repeat step (1) to recalculate edge weights between the clustered node and remaining graph nodes and then step (2) in order to continue clustering the nodes as long as their edge weight is higher than the threshold value. After this has been done, the k intermediate feature lists are aggregated to $c < k$. So, the output of this phase is $c_j < k_j$ and the feature lists for each partition, P_j $FS^j = \{\overline{\mathrm{FS}_1^j}, \ldots, \overline{\mathrm{FS}_{cj}^j}\}$.

D. Second Ensemble Layer of the Dynamic MI-based Multi-Label Feature Selection Algorithm

In the second ensemble layer, the ensemble FS method [17] takes into account the dynamic change of the selected features along with the class and dynamic global weight of the feature. In addition, the ensemble FS method measures the importance of the feature based on a criterion that has been adapted in order to maximize the dependency between the candidate feature and all class labels and minimize the conditional redundancy between the candidate feature and the selected features [36] [37] [6]. The maximal relevancy, i.e., the correlation and the minimal redundancy condition, ensures that the selected feature subset contains the most class-discerning information.

The DMM-EFS is based on a few factors which have been described as follows:

1) The first factor is the dynamic sample weight, and it considers the weight $w(\overline{FS}, h, q)$.of feature h in the feature list q.

2) The second factor is the average weight (ASW_h) of feature h from all the FS lists (samples). Based on this factor, the DMM-EFS is able to evaluate the importance of each feature in all the partitions P and all FS lists Q using the following equation:

$$ASW_h = \sum_{p\in P} \sum_{q\in Q} w(\overline{FS}, h, p, q) \tag{11}$$

3) The third factor is the size (ai) of the selected features in the sample by the FS method (i.e., ai represents the size of the features that appear in the sample). This factor is used to dynamically reduce the feature weight.

4) The fourth and last factor is the maximum sample weight of the overall samples which is used to map the feature weight $fw(i,j)$ into a higher value if the assigned value of the weight at the level of all the samples are not high.

The proposed algorithm, as shown in algorithm 1, uses the dynamic sample weight (DSW) and defines the rest of the aspects as follows: a set of samples or FS methods $D^{t\times n}$, where t is a unique set of features, while n is the number of used base FS methods (number of samples). Dynamic feature weight (DFW) is the weight of each feature in each of the base FS method or in each sample. DSW is the number of base methods that selects feature using the following equations:

$$SFWij = \frac{(fw(i,j) * ASWj * ai)}{ASW_i} \tag{12}$$

$$DSWj = \frac{DSWj}{sumSFj} \tag{13}$$

As shown in the algorithm 1, the DMM-EFS consists of several steps. With Step (i), it calculates the size of the features in each sample. Then, with Step (ii), it measures the maximum weight of the features in the sample of each sample. Following this, Step (iii) finds out the average weight of the feature j in all the samples. If feature j is selected from several samples by using FS methods, then it has various weights (different weights in different samples); this step will calculate the average weight of feature j in all the samples. With Step (iv), it calculates the overall weight of the feature in all the samples, this step computes the weight of feature j in all the FS methods (samples). (Note: For each sample, a FS method is applied to the selected feature on the basis of their weight). After that, Step (v) calculates the dynamic global weight of each feature from the weights of the feature j in all the samples. Finally, Step (vi) selects the features based on their calculated dynamic global weight. This means that features with dynamic sample weigh greater than the threshold is selected using the ensemble algorithm.

Algorithm 1: DMM-EFS

Input: *sample feature matrix // contains the weight of each feature in each sample*

Output: *A new subset of features*
Begin

Step 1: Find the size of features in each sample
ai =*Calculate_Sample_Size* (si)

Step 2: Find the max weight in each sample samples
MSW_i = *Calculate_max_**weight*** (si)

Step 3: Find the average weight of feature j in all samples
ASW_j=*CalculateAverageWeight (feature j).*

Step 4: Calculate weight of feature in all samples
$for\ j = 1\ to\ t$ *do // Number of Features*
$for\ i = 1 to\ n\ do$ *// Number of Samples*
$SFWij = (fw(i,j) * ASWj * ai) / ASW_i)$
//$SFWij$ *is the weight of feature i in sample j*
Endfor
End for

Step 5: Calculate Dynamic global weight of each feature
$for\ j = 1\ to\ t\ \ do\ //\ number\ of\ features$
$for\ i = 1\ to\ n\ do\ //\ number\ of\ samples$

$if\ \ feature\ \ j\ appears\ in\ the\ sample\ i\ then$
$Updating\ \ DSWj = DSWj\ +\ SFWij$
$DSWj\ =\ DSWj\ /\ sumSFj$
$Endfor$
$endfor$

Step 6: select features based on their calculated dynamic global weights
$F_{setD} = \{\}$ *// final selected features set*
$for\ j\ = 1 to\ t\ do$
$if\ DSWj >= threshold\ then$
FR_j
$\leftarrow Compute\ feature_{redundancy}(f_j, fs) with\ all\ the\ selected\ feature\ fs\ \in\ F_{setD}$
if Calculated information is less than α for all selected features in F then
F←F∪{f}
end
$newsubsetD = newsubsetD \cup feature\ j$
End if
end for
$Return\ newsubsetD$

V. CLASSIFCATION MODELS

For the evaluation, two multi-label classification learning models: chain of classifier (CC), which is based on binary relevance method, and AdaBoost.MH are adopted. CC model [38] [39] can be trained independently using different datasets. This work utilizes three proven binary classifiers, namely, support vector machines (SVM) classifier, K-nearest neighbor (KNN) classifier, and Naive Bayes (NB) [40] [41]. These classifiers can be selected to construct the classifier chain. Based on different sets of domains, the training of each classifier was done independently using a data set from each domain. On the other hand, AdaBoost.MH model can adaptively adjust the weight distribution of the training samples and choose the best weak classifier out of the sample weight distribution by consistently combining all the weak classifiers, and vote by a given weight in order to build a strong classifier. AdaBoost.MH is a multi-label version of AdaBoost algorithm [42] [15]. However, these models were selected, as they have been considered as two of the high-performance state-of-the-art classification models [15] [42] [39], and they are often used to solve problems related to high dimensionality of datasets.

VI. EXPERIMENTAL WORK

This section describes the datasets and measurements that have been used to evaluate the proposed method. The experiments were evaluated using a 5-fold cross-validation technique.

A. Multi-Label Text Dataset

Table I presents the three datasets that have been used in this work: Reuters-21578, Bibtex, and Enron and are publicly available for the multi-label text domain. In Table I, the number of features, instances, labels, cardinality, and average imbalance ratio per label (avgIR) are displayed. Cardinality measures the average number of classes for each instance, whereas density denotes the cardinality divided by the total number of labels. The datasets are available at the Mulan website (http://mulan.sourceforge.net/datasets-mlc.html).

TABLE I. SUMMARY DESCRIPTION OF THE MULTI-LABEL TEXT CLASSIFICATION DATASETS

Dataset	Instances	Features	Labels	Cardinality	avgIR
Reuters-21578	6000	500	103	1.462	54.081
Bibtex	7395	1836	159	2.402	12.498
Enron	1702	1001	53	3.378	73.953

B. Evaluation Metric

The results of the experiment on multi-label classification were measured using the following three evaluation metrics: Precision, Recall, and F measure [39] [11] [43] [44], using equations 14, 15, and16, respectively. These evaluation metrics are well-known in this domain for making comparisons.

$$\mathrm{M\_PRECISION} = \sum_{i=1}^{d} \frac{\mathrm{TP_i}}{\mathrm{PT_i+FP_i}} \tag{14}$$

$$\mathrm{M\_RECALL} = \sum_{i=1}^{d} \frac{\mathrm{TP_i}}{\mathrm{PT_i+FP_i}} \tag{15}$$

$$\mathrm{M_{F\beta}} = \sum_{i=1}^{d} \frac{(\beta^2+1)\mathrm{Pr}\times\mathrm{Re}}{\beta^2\mathrm{Pr}+\mathrm{Re}} \tag{16}$$

VII. EXPERIMENT RESULTS

This section evaluates and compares the five individual FS methods: Information Gain (IG), F-score (F), Normalized Mutual Information (NMI), Relief (R), and Mutual Information (MI) and the multi-label ensemble FS methods: multi-label mean-based ensemble feature (ME-mean) selection method and multi-label plurality vote ensemble FS method (ME-PV) with our proposed method, dynamic multi-label two layers MI and clustering-based ensemble FS method (DMMC-EFS).

Three experiments are conducted: The first experiment (Experiment I) is conducted using conventional and ensemble FS methods on Reuters-21578 corpus; the second, experiment (Experiment II) is conducted using conventional and ensemble FS methods on Bibtex corpus; and the third experiment (Experiment III) is conducted using conventional and ensemble FS methods on Enron corpus.

A. *Experiment I: Evaluation of the Proposed Ensemble FS Method and the Conventional FS Methods on Reuters-21578 Corpus*

This subsection evaluates five state-of-the-art conventional multi-label FS methods (FSMs): IG, F, NMI, R, and MI and three multi-label ensemble FS methods: ME-mean, ME-PV and DMMC-EFS. The effect of these methods is studied using two classification models: CC model, which combines three classifiers (SVM, KNN and NB), and AdaBoost.MH.

All experiments in this subsection are conducted on Reuters-21578 corpus benchmark dataset. The macro-averaging *F*-measure of the CC and AdaBoost.MH with the eight FS methods (FSMs) are displayed in Table II.

With a focus only on the conventional multi-label FS methods, both NMI and MI multi-label FS methods achieve the best performance with all the classifiers. The performance of the two conventional FS methods: IG and F-score is below average. The main reason is that both NMI and MI multi-label FS methods use feature-class mutual information to select relevant features.

With a focus on both multi-label ensemble and conventional FS methods, the results from all the multi-label ensemble methods are better than the results that are obtained using the conventional FS methods. DMMC-EFS multi-label ensemble method achieves the highest performance in terms of macro-averaging F-measure outperforming both the multi-label ensemble and conventional methods. As mentioned in Section 4, DMMC-EFS considers the feature-class and feature-feature correlation in order to select relevant and non-redundant features and also the dynamic change of the selected features along with the class and dynamic global weight of the feature.

A range of 71–90% was achieved by all the classifiers. AdaBoost.MH displays higher classification performance than the CC on the Reuters-21578 corpus in terms of all the multi-label ensemble and conventional FS methods. This may be due to the fact that AdaBoost.MH model produces alternating decision trees that can handle multi-label data.

In general, all the classification models with all the multi-label ensemble FS methods (ME-mean, ME-PV, and DMMC-EFS) achieve good results in terms of prediction performance on the Reuters-21578 (a high dimensional dataset) corpus. This is expected as the ensemble FS methods exploits the several FS methods by combining their strengths.

B. *Experiment II: Evaluation of the Proposed Ensemble FS and the Conventional FS Methods on Bibtex Corpus*

This subsection evaluates five state-of-the-art conventional multi-label FS methods: IG, F, NMI, R, and MI and three multi-label ensemble FS methods: ME-mean, ME-PV, and DMMC-EFS. The effect of these methods is studied using two classification models: CC model, which combines three classifiers (SVM, KNN and NB) and AdaBoost.MH. All the experiments in this subsection have been conducted on Bibtex corpus benchmark dataset. The macro-averaging F-measure of the CC and AdaBoost.MH along with the eight FSM selection methods are shown in Table III.

With a focus only on the conventional multi-label FS methods, unlike experiments on Reuters-21578 corpus, experiments on Bibtex corpus show that R multi-label FS method achieves the best performance among all the conventional FS methods irrespective of the classifier used. R, as a feature evaluation measure, more often selects smaller number of features than the other FS methods, without degrading the performance of the classifiers. This could be due to the fact that R considers interactions among the features [27].

With a focus only on the multi-label ensemble FS methods, DMMC-EFS multi-label ensemble method achieves the best performance with all the classifiers. As mentioned in Section 4, DMMC-EFS takes into account the feature-class and feature-feature interaction in order to select the relevant and non-redundant features and the dynamic change of selected features along with the class and dynamic global weight of the feature. Its results on Bibtex corpus is slightly higher than its results on Reuters-21578 corpus. This is due to the fact that Reuters-21578 dataset has higher dimensionality than Bibtex corpus.

TABLE II. PERFORMANCE (F-MEASURE) OF CC AND ADABOOST.MH WITH ALL MULTI-LABEL ENSEMBLE AND CONVENTIONAL FS METHODS ON REUTERS-21578

Feature Selection method	AdaBoost.MH	CC
IG	74.13	71.67
R	81.1	79.54
NMI	86.01	81.6
MI	85.23	80.9
F	77.17	76.36
ME-mean	86.62	82.62
ME-PV	86.58	82.99
DMMC-EFS	89.96	87.41

TABLE III. PERFORMANCE (F-MEASURE) OF CC AND ADABOOST.MH WITH ALL MULTI-LABEL ENSEMBLE AND CONVENTIONAL FS METHODS ON BIBTEX CORPUS

Feature Selection Method	AdaBoost.MH	CC
IG	75.25	70.85
R	86.03	83.28
NMI	84.41	80.2
MI	84.32	80.82
F	73.84	70.13
ME-mean	84.42	80.52
ME-PV	83.7	80.39
DMMC-EFS	91.31	88.81

With a focus on both the multi-label ensemble and conventional FS methods, DMMC-EFS multi-label ensemble methods achieve better results than those obtained using all the conventional FS methods. R multi-label FS method attain better performance than ME-mean and ME-PV multi-label ensemble FS methods. The ME-mean and ME-PV ensemble FS methods, which use NMI and MI, dominate other methods when they are combined, and the final feature list are strongly biased toward their choice. So, the ME-mean and ME-PV ensemble FS methods act as a single MI FS method. However, in terms of macro-averaging F-measure, the DMMC-EFS multi-label ensemble method performs the best among the other multi-label ensemble and conventional methods. As it has been mentioned above, DMMC-EFS takes into account feature-class and feature-feature interaction in order to select relevant and non-redundant features and the dynamic change of selected features along with the class and dynamic global weight of the feature.

A range of 70– 91% of performance is achieved by all the classifiers. AdaBoost.MH gave higher classification performance than the CC on Bibtex corpus with all the multi-label ensemble and conventional FS methods. This may be due to the fact that AdaBoost.MH model produces alternating decision trees that can handle multi-label datasets. In general, all the classification models (CC and AdaBoost.MH) with the multi-label ensemble FS methods (ME-mean, ME-PV and DMMC-EFS) achieve good results (between 80% and 91%) in prediction performance on Bibtex corpus' high dimensional datasets.

C. *Experiment III: Evaluation of the Proposed Ensemble FS and Conventional FS Methods on Enron Corpus*

This subsection examines five state-of-the-art conventional multi-label FS methods: IG, F, NMI, R, and MI and three multi-label ensemble FS methods: ME-mean, ME-PV, and the proposed method (DMMC-EFS). The effect of these methods is studied using two classification models: CC model, which combines three classifiers (SVM, KNN, and NB), and AdaBoost.MH. All the experiments in this subsection are conducted on Enron corpus benchmark dataset. The macro-averaging F-measure of the CC and AdaBoost.MH with the eight FSM selection methods are presented in Table IV.

Considering only the conventional multi-label FS methods, similar to the results on the Reuters-21578 corpus dataset (as shown in Table II), both NMI and MI multi-label conventional FS methods achieve the best performance on Enron corpus among all the conventional FS methods regardless of which classifier has been used. Considering only the multi-label ensemble FS methods, DMMC-EFS multi-label ensemble method achieves the best performance with all the classifiers. On both the multi-label ensemble and conventional FS methods, both DMMC-EFS and E-mean multi-label ensemble methods achieve performances higher than that of all the conventional FS methods. Both NMI and MI multi-label conventional FS methods attain better performance than ME-PV multi-label ensemble FS methods. However, DMMC-EFS multi-label ensemble method achieves the highest performance in terms of macro-averaging F-measure among both the multi-label ensemble and conventional methods.

TABLE IV. PERFORMANCE (F-MEASURE) OF CC AND ADABOOST.MH WITH ALL MULTI-LABEL ENSEMBLE AND CONVENTIONAL FS METHODS ON ENRON CORPUS

Feature Selection method	**AdaBoost.MH**	**CC**
IG	78.83	74.82
R	85.19	82.67
NMI	86.41	83.34
MI	86.7	84.2
F	77.7	73.88
ME-mean	87.27	83.37
ME-PV	86.11	84.57
DMMC-EFS	91.79	89.54

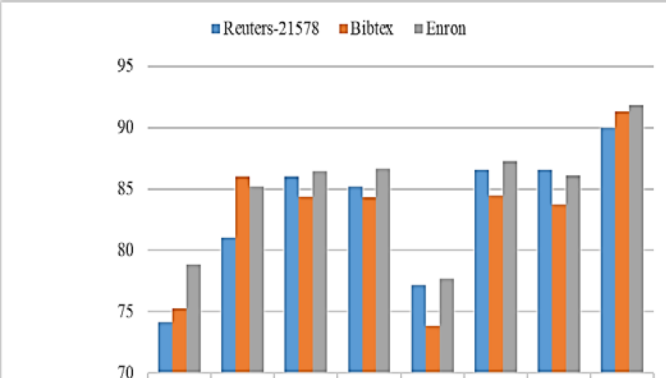
A range of 73–92% of performance is achieved by all the classifiers. In general, all the classification models with multi-label ensemble FS methods achieve good results between 84% and 91% of F-measure in the prediction performance on Enron corpus' high dimensional datasets.

VIII. RESULTS DISCUSSION

In order to evaluate and compare the performance of the conventional multi-label FS methods, ensemble FS methods and our proposed DMMC-EFS on all the data sets, the obtained results are presented in Fig. 2.

It can be observed in Fig. 2 that the F-measure is within the range of 86–91.7%; this demonstrates that the multi-label text classification models can be improved if the inherited high dimensionality problem is reduced. Fig. 2 also validates the stability of the proposed DMMC-EFS and the conventional methods. Stability is defined as the ability to behave the same way regardless of what dataset is being used. Since the complexity of the datasets varies, and they are derived from different sources, the stability could be found to be different for all the conventional FS methods. The proposed DMMC-EFS multi-label ensemble method is the most stable method, as it always achieves the top rank, and their results on all datasets is mostly consistent, which means that. It outperforms all the other methods on all the datasets, and the difference in the values of its performance from one dataset to another is minute.

By comparing the behavior of both the ME-mean and ME-PV multi-label ensemble FS methods with the behavior of both the NMI and MI multi-label conventional FS methods using the data presented in Tables II–IV, we notice that the ME-mean and ME-PV behave like the conventional FS methods and their results are effected by NMI and MI. As stated in [29], if the similar FS methods are combined, the result will be strongly biased towards their aggregated outputs. In fact, NMI and MI have similar underlying concepts, which means that they are derived from the same mathematical and statistical concepts. Therefore, they tend to produce similar outputs. NMI and MI [29] dominate other methods when they are combined, and the final feature list are strongly biased toward their output. This supports our hypothesis that similar methods outputs should be clustered together, so as to ensure that they have less chance to overvote the other methods which eventually widen the output diversity.



	IG	R	NMI	MI	F	ME-mean	ME-PV	DMMC-EFS
Reuters-21578	74.13	81.1	86.01	85.23	77.17	86.62	86.58	89.96
Bibtex	75.25	86.03	84.41	84.32	73.84	84.42	83.7	91.31
Enron	78.83	85.19	86.41	86.7	77.7	87.27	86.11	91.79

Fig. 2. Performance of All Multi-Label Ensemble and Conventional FS Methods on All Data Sets.

IX. Conclusion

This paper presents a scalable multi-label classification method that can handle the high dimensionality problem of the multi-label datasets. Firstly, this paper investigates the several state-of-the-art conventional multi-label FS methods. In addition, this paper proposes two multi-label ensemble FS methods: multi-label mean ensemble (ME-mean) FS method and multi-label plurality vote ensemble (ME-PV) FS method. Finally, this paper proposes a new dynamic multi-label two layers MI and clustering-based ensemble FS (DMMC-EFS) method that takes into account the 1) dynamic global weight of the feature; 2) heterogeneous ensemble 3) maximum dependency and relevancy and minimum redundancy of the features. The results show that the proposed multi-label FS methods significantly outperformed the other state-of-the-art conventional and ensemble multi-label FS methods. To conclude, it can be stated that an enhanced ensemble FS method, which takes into account the dynamic global weight of the feature, heterogeneous ensemble, and max dependency and relevancy and minimum redundancy of the features, can overcome the high dimensionality of the multi-label datasets and improve the performance of the multi-label text classification system. In future, it is recommended to extend the proposed method by adding more sophisticated feature selection methods to it. Additionally, it is also recommended to examine the performance of DMM-EFS method using different languages and datasets.

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ARIMA Model for Accurate Time Series Stocks Forecasting

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***Abstract*—With the increasing of historical data availability and the need to produce forecasting which includes making decisions regarding investments, in addition to the needs of developing plans and strategies for the future endeavors as well as the difficulty to predict the stock market due to its complicated features, This paper applied and compared auto ARIMA (Auto Regressive Integrated Moving Average model). Two customize ARIMA(p,D,q) to get an accurate stock forecasting model by using Netflix stock historical data for five years. Between the three models, ARIMA (1,1,33) showed accurate results in calculating the MAPE and holdout testing, which shows the potential of using the ARIMA model for accurate stock forecasting.**

Keywords—ARIMA; forecasting; prediction analysis; time series; stocks forecasting; data mining; big data

I. Introduction

The increasing availability of historical data with the need for production forecasting has attracted the attention of Time Series Forecasting (TSF), which gives a sequence of predicting future values, especially with the limitations of traditional forecasting, such as complexity and time-consuming [1]. The future prediction of system behavior by TSF based on current and past information. The role of TSF is part of several real-world problems, such as network traffic, petroleum, weather forecasting, and financial markets [2]. The empowered institutions and individuals to make decisions to invest and the need to develop plans and strategy of future endeavors made the prediction exciting area for the domain researchers to work and improve the predictive models [3, 4, 5]. Especially when the decision-making process, in general, considered not accessible due to the need for reading and extracting from the massive amount of data [6]. To get the best result of the stock market, forecasting stock prices become an attractive pursuit for investors. Therefore, several models and techniques in the past years have been developed to stock prices prediction. Data in time series included as points listed in time order, which is sequence of discrete-time equally space in time, where the forecasting will be predicting the future by analyzing observed points in the series [7].

From artificial intelligence perspectives Artificial Neural Network (ANN) model, considered one of the most popular models, especially with its ability to learn patterns [3], where the stored structure used to model the problem [8]. In stock price prediction studies, some researches worked on engage ANN [9, 10, 11]. From statistical models' perspectives, autoregressive integrated moving average (ARIMA) models considered one of the most models extensively used in economics and finance fields [3], as well as stock forecasting [12, 13, 14, 15]. However, the prediction of the stock market in time series considered one of the most challenging issues because of it volatile and noise features [16, 17]. Where the change of stock price considered as non-linear and non-stationary, which makes getting reliable and accurate prediction quite challenging [18]. In view of the critical play role of forecasting stock to setting a trading strategy, determining the actions for appropriate timing to buy or sell stocks and to study future investment opportunities as well as the importance of developing and improving time series forecasting models and study its effectiveness and success, this paper aim to get the accurate stocks forecasting model by comparing the results of accuracy of auto ARIMA model and two customize ARIMA (p,D,q) models which will be applied on Netflix stocks historical data for last five year. By applying this model to forecast for Netflix's future, especially since it showed an essential role in people's life today with what the world is facing from COVID-19. Therefore, it is quite essential having a clear understanding of the present as well as forecasting the future when aiming to have a safe investment. It also contributes to understanding the role of the time series forecasting ARIMA model and the accuracy of its techniques.

The rest of the paper is organized as follows. Section II literature review. Section III methodology, Section IV result and discusses and the conclusion in Section V.

II. Literature Review

Improving the accuracy of stock forecasting was part of cao et al. [18], study, where they combined Empirical Mode Decomposition (EMD) with the Long Short-Term Memory (LSTM) in their proposed model, where the result showed better performance. It has also been studied the efficiency to improve the predictability of stock returns by proposing simple way which was based on existing predictors with low correlations instead of new powerful predictors [19]. As well as the complexity of stock data has been discussed and its need for efficient prediction system and proposed model which shows better accuracies forecasting [11]. Using hybrid models was part of the studies to face the complexity of linear and nonlinear components where the ANN-ARIMA hybrid model has been evaluated and showed more accurate results than the conventional ARIMA-ANN model [12]. The majority of prior research on stock time series forecasting focused on proposing an accurate prediction model, which is considered as one of the challenges on the domain.

III. Methodology

Prediction the future of stocks values using ARIMA model it will be by testing the auto ARIMA values as well as build customize ARIMA (p,D,q) models to get better forecasting model. The ARIMA model applied on real Netflix stock data which is available for public on Yahoo! Finance [20]. The dataset contains Netflix daily stock price data for five years, starting from 7 April 2015 to 7 April 2020. The data in Fig. 1, describes the date, open which is the price at the beginning of the day, high which is the highest price during the day, low which is the lowest price during the day, close which is the price at the end of the day, adjusted closing which is the price of stock's closing price amended to accurately reflect that stock's value after accounting for Netflix actions, and the volume which is the number of stocks of a security traded during that day. The forecasting process adjusted closing values which had only counted, since it is representing the real closing value of the day as well as this value has been scaled for more accurate readings. The model applied using R language in R Studio. Determine the model accuracy and the comparing between the several experiments in the model will be based on calculate Autocorrelation Functions (ACFs), Partial Autocorrelation Function (PACF) as well as Mean Absolute Percentage Error (MAPE).

A. ARIMA Model

Auto Regressive Integrated Moving Average (ARIMA) is a model describes time series given based on observed value which can be used to forecast future values. Appling ARIMA models on Any time series show patterns with no random white noise and non-seasonal [21]. The model introduced by Box and Jenkins in 1970. To generate short-term forecasts, ARIMA models showed efficient capability outperformed complex structural models [3]. The future value of a variable in ARIMA model is a combination of linear to the past values and errors, expressed as follows:

$$Y_t=\phi_0+\phi_1 Y_{t-1}+\phi_2 Y_{t-2}+\ldots+\phi_p Y_{t-p}+\varepsilon_t-\theta_1\varepsilon_{t-2}-\ldots-\theta_q\varepsilon_{t-q} \quad (1)$$

Where,

Y_t is the actual value and E_t is the random error at t,ϕ_i and θ_j are the coefficients, p and q are integers that are often referred to as autoregressive and moving average, respectively. [22].

B. Auto ARIMA and ARIMA (p, D, q) Models Implementation

Exploring Netflix stocks data from 7th April 2015 to 7th April 2020, showed the non-stationary characteristics of time series as shown in Fig. 2.

```
Date : Factor w/ 1260 levels "2015-04-07","2015-(
Open : num 60.5 61.2 63 64.4 67.2 ...
High : num 60.8 63.1 63.1 65 69.3 ...
Low : num 60 61.2 62.1 63.9 67.1 ...
Close : num 60.5 63 62.8 64.9 67.8 ...
Adj.Close : num 60.5 63 62.8 64.9 67.8 ...
Volume : int 9977100 22327900 13455400 22367100 4
```

Fig. 1. Description of Data.

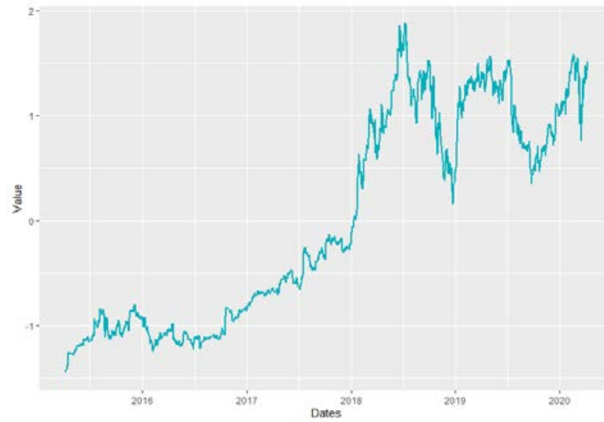

Fig. 2. Representing of Netflix Stocks Adjusted Closing Values.

To reduce the noise and uncover patterns in the data as well as smoothing the data, moving average calculates, where measured as weekly, monthly and yearly value was is shown in Fig. 3. The weekly moving average (K=7) is more looking like as the data itself, and to not lose much of the data pattern the weekly moving average is showing as the most appropriate option.

Fig. 4 shows the decomposing of the time series data which identifying seasonality, trends, data and reminder, where the seasonality was removed to improve the stationary of data.

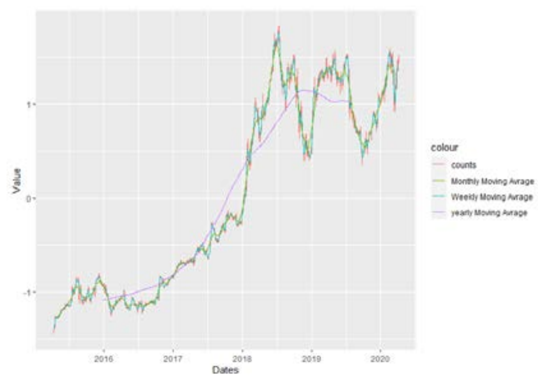

Fig. 3. Representing of Moving Average Values.

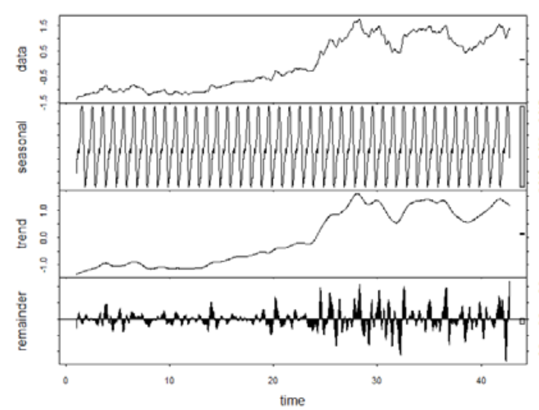

Fig. 4. The Decomposing of Data.

ACF and PACF shown in Fig. 5 represent the data non-stationary form. The data converted to stationary by changing the differencing as shown in Fig. 6.

Dicky fuller test used to confirm that the data became stationary. Fig. 7 shows the values before changing the differences and Fig. 8 shows the data became stationary with first-difference.

Appling auto ARIMA which showed (4,1,4) as its value, where showing some significant spikes ACF and PACF and it's over the limits as shown in Fig. 9.

Customize ARIMA (1,1,33) showed no significant spikes above the limits of ACFs and PACFs as shown in Fig. 10, which means more accurate model of Auto ARIMA.

Customize ARIMA (1,2,33) tested as well in order to get the best accuracy, as it showed no significant spikes above the limits of ACFs and PACFs as shown in Fig. 11, and not much different from (1,1,33) results.

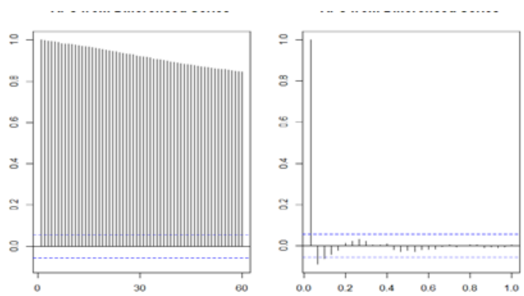

Fig. 5. ACF and PACF before Change the Differences.

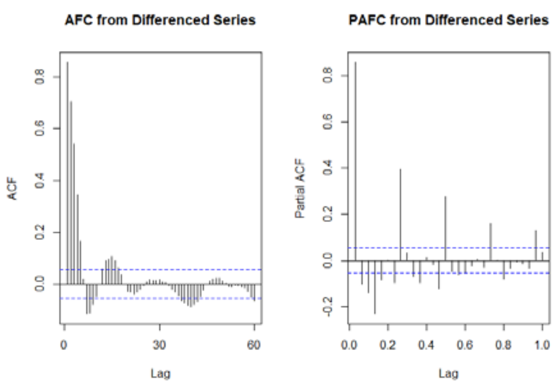

Fig. 6. ACF and PACF after Change the Differences.

```
        Augmented Dickey-Fuller Test

data:  $nocount
Dickey-Fuller = -2.4535, Lag order = 10, p-value = 0.3863
alternative hypothesis: stationary
```

Fig. 7. Dicky Fuller Test before Change the Differences.

```
        Augmented Dickey-Fuller Test

data:  count1
Dickey-Fuller = -8.4792, Lag order = 10, p-value = 0.01
alternative hypothesis: stationary
```

Fig. 8. Dicky Fuller Test after Change the Differences.

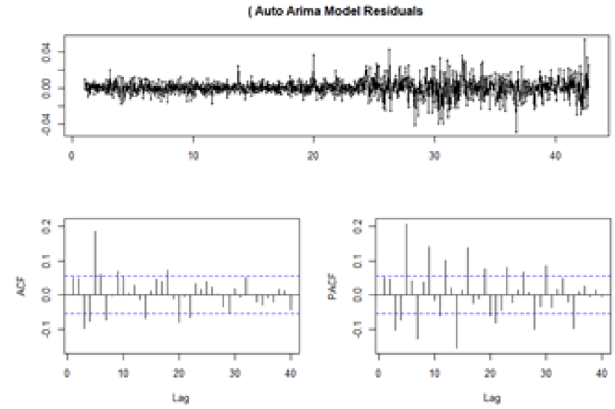

Fig. 9. Auto ARIMA ACF and PACF.

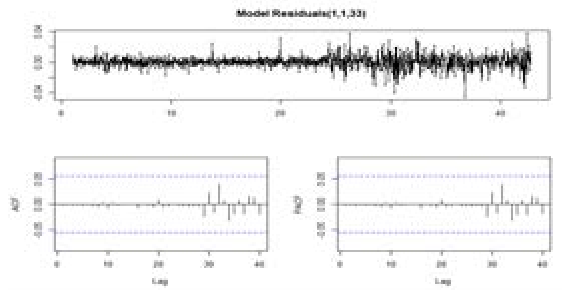

Fig. 10. ARIM (1,1,33) ACF and PACF.

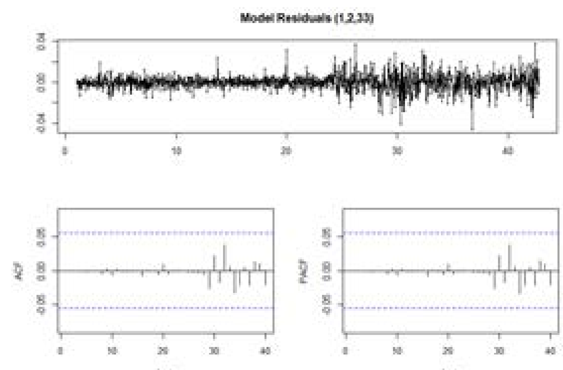

Fig. 11. ARIM (1,2,33) ACF and PACF.

Forecasting the three models of ARIMA, Auto ARIMA (4,1,4) and ARIMA (1,2,33) showed the same prediction which predicted that stocks will go up while in ARIMA (1,1,33) has different prediction where predicted that the stocks will remain the same as shown in Fig. 12.

Comparing the accuracy results by calculating Mean Absolute Percentage Error MPE showed no much difference between the three models see Fig. 13, where the accuracy of auto ARIMA is 98.88 %, ARIMA (1,1,33) is 99.74% and ARIMA (1,2,33) is 99.75%.

The MAPE calculating showed that the accuracy of forecasting the three models have almost similar value , since Auto ARIMA(4,1,4) showed significant spikes of its ACF and PACF it will not take the results of this model, while the ARIMA (1,1,33) and ARIMA (1,2,33) it has almost the same accuracy , yet it's forecasting to give different values, to reach the best accuracy further tests have been done by holdout 50% of data and forecasting rest 50% of data and then comparing the result with actual data, where ARIMA (1,1,33) showed better result from ARIMA (1,2,33) as shown in Fig. 14 and Fig. 15.

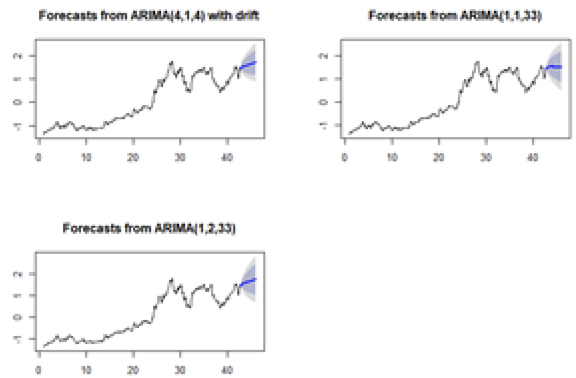

Fig. 12. Forecasting Auto ARIMA (4,1,4), ARIMA (1,1,33) and ARIM (1,2,33).

```
> accuracy(NTcast13)
                        ME        RMSE         MAE       MPE     MAPE       MASE       ACF1
Training set -6.774307e-06 0.009297113 0.006432601 0.2268033 1.112156 0.03114079 0.05024813
> accuracy(NTcast23)
                       ME        RMSE         MAE       MPE     MAPE       MASE         ACF1
Training set 0.0003458213 0.007950966 0.005485822 0.1850255 0.925813 0.02655735 -0.001514296
> accuracy(NTcast33)
                        ME        RMSE         MAE      MPE      MAPE       MASE         ACF1
Training set -3.572197e-05 0.007944394 0.005473787 0.198077 0.9244278 0.02649909 8.743669e-06
```

Fig. 13. Accuracy Results.

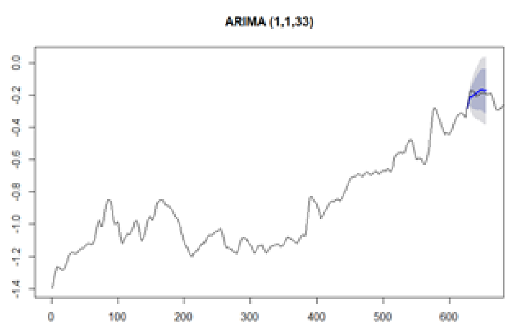

Fig. 14. Hold out Test on ARIM (1,1,33).

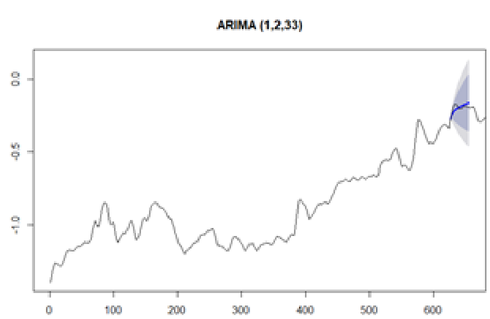

Fig. 15. Hold out Test on ARIM (1,2,33).

IV. Results and Discussion

ARIMA (1,1,33) model showed better accuracy. Although within the measurement of MAPE, the accuracy was 99.74% and ARIMA (1,2,33) was 99.75% which is almost the same. However, owing to its result from holdout test it is considered the best accuracy among the three models. The prediction of Netflix stocks on ARIMA (1,1,33) showed continuity in value, where this prediction to 100 days which mean for next three months, there will be no significant increase in the value of stocks as shown in Fig. 16.

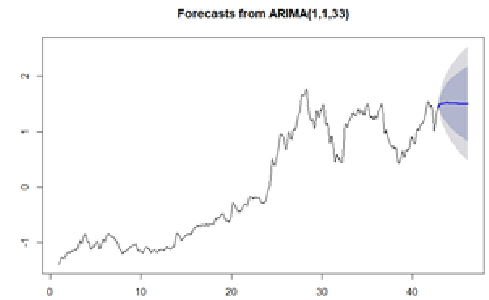

Fig. 16. The Prediction of Netflix Stocks on ARIM (1,1,33).

V. Conclusion

The research used Netflix stocks historical data for the past five from 7 April 2015 to 7 April 2020 to compare the results of auto ARIMA model and two customize ARIMA (p,D,q) models. After several tests ARIMA (1,1,33) showed accurate results in its calculating values which showed the potential of using ARIMA model on time series data to get accurate prediction on stocks data which will help investors in stocks in their investment decisions. The forecasting of Netflix stocks on ARIMA (1,1,33) showed continuity in value.

This research compared the results and calculated the accuracy based on one model which is ARIMA model the future work will compare more than one model and calculate the accuracy to reach the most accurate one.

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M2C: A Massive Performance and Energy Throttling Framework for High-Performance Computing Systems

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***Abstract*—At the Petascale level of performance, High-Performance Computing (HPC) systems require significant use of supercomputers with the extensive parallel programming approaches to solve the complicated computational tasks. The Exascale level of performance having 10^{18} calculations per second is another remarkable achievement in computing with a fathomless influence on everyday life. The current technologies are facing various challenges while achieving ExaFlop performance through energy-efficient systems. Massive parallelism and power consumption are vital challenges for achieving ExaFlop performance. In this paper, we have introduced a novel parallel programming model that provides massive performance under power consumption limitations by parallelizing data on the heterogeneous system to provide coarse grain and fine-grain parallelism. The proposed dual-hierarchical architecture is a hybrid of MVAPICH2 and CUDA, called the M2C model, for heterogeneous systems that utilize both CPU and GPU devices for providing massive parallelism. To validate the objectives of the current study, the proposed model has been implemented using bench-marking applications including linear Dense Matrix Multiplication. Furthermore, we conducted a comparative analysis of the proposed model by existing state-of-the-art models and libraries such as MOC, kBLAS, and cuBLAS. The suggested model outperforms existing models while achieving massive performance in HPC clusters and can be considered for emerging Exascale computing systems.**

Keywords*—High performance computing; Exascale computing; compute unified device architecture

I. Introduction

The High-Performance Computing (HPC) can practice computing power and parallel processing techniques to resolve extensive enigmas in various disciplines, e.g., medicine, engineering, commercial enterprise, smart cities [51] and so on, by providing much higher performance than that of a traditional desktop computer [1, 2]. A traditional computer system has a single CPU in general. However, an HPC system usually consists of a community of CPUs where each processor contains multi-cores along with its local memory to execute a variety of complicated tasks [38]. HPC systems utilize supercomputers and parallel processing techniques to execute extensive jobs. Therein, thousands of processors operate in parallel to solve extensive problems by supercomputing. On the other hand, large problems are broken down into smaller ones that could be resolved at the same time to enhance the overall performance of HPC systems by parallel computing. If a traditional desktop computer takes 200 hours to complete a specific task while it could be completed in 1 hour by utilizing 200 computers at once by the HPC system. Therefore, a single desktop computer might not be as useful as it could be while utilizing all the resources collectively as a community.

There exist various advancements in the performance of the HPC system from GigaScale to Terascale, to Petascale, to Exascale, each of which constitutes an extraordinary improvement in computing performance. HPC system provides high-end designing and simulation environments, helps applications to deal with marketing delivery challenges by providing the facility to accelerate or even get rid of prototyping and testing phases. The HPC system not only enhances the quality but also predict the failure rate to enhance the overall performance of the product [4, 13]. Moreover, the HPC system supports existing technologies in the research and development process to deliver products to the marketplace more quickly. Similarly, organizations and industries use supercomputers before the actual implementation to build and examine their strategies [5]. The fastest supercomputer can currently solve complex problems using Petascale systems that can perform 10^{15} (quadrillion) calculations each second. Though these Petascale systems are going well in this era, the next milestone in computing advancement is to pace relatively towards high-performance Exascale systems offering outstanding computing power. These advance and powerful HPC systems will reveal many Scientific mysteries and will have a fathomless impact on everyday life [1, 2, 3].

The architecture of such a system might vary from conventional order. The following two options could be possible in this regard. First, all the accelerated processing General Purpose Graphics Processing Unit (GPGPU), and conventional CPU devices will reside exclusively within the node. In the second option, accelerated devices will be separated at the cabinets/rack level. We have shown the broad level conceptual depiction of future Exascale supercomputer (see Fig. 1), in which the heterogeneous system is comprised of a number of racks that can communicate with each other over the network. These racks are further consisting of multiple nodes and additional components resided in it where each node contained Heterogamous Processing Chip (HPC) having several heterogeneous devices including CPUs GPGPUs as well.

Current supercomputers cannot deliver such a high level of computation under the power consumption limitation. Although developers can extend the cores in the current Petascale systems to devise a way towards Exascale computing system, the challenge of power consumption still exists [43]. The United States Department of Energy has pointed out some primary constraints for the roadmap of Exascale computing systems by considering the financial and power consumption limitations. These constraints include the power consumption not more than 25 to 30 Mega Watts, system development cost around 200 million USD by 2020 and integrated multi-cores no more than 100 million [6, 8, 45].

Current technologies are facing various challenges to meet the above-defined constraints (see Fig. 2) [7].

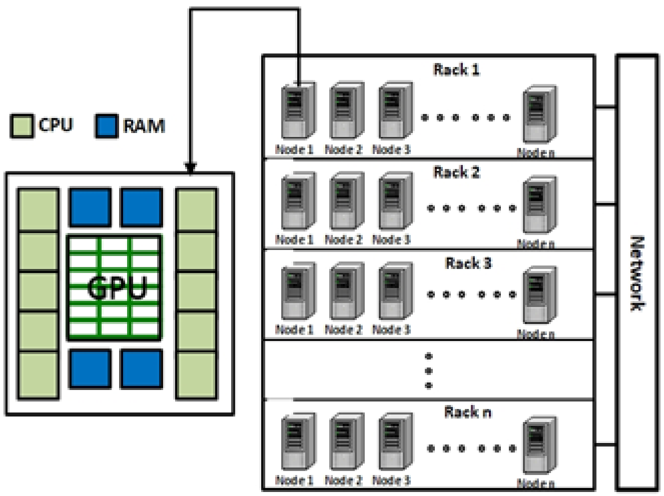

Fig. 1. Predictive Structure of the Exascale Supercomputing System.

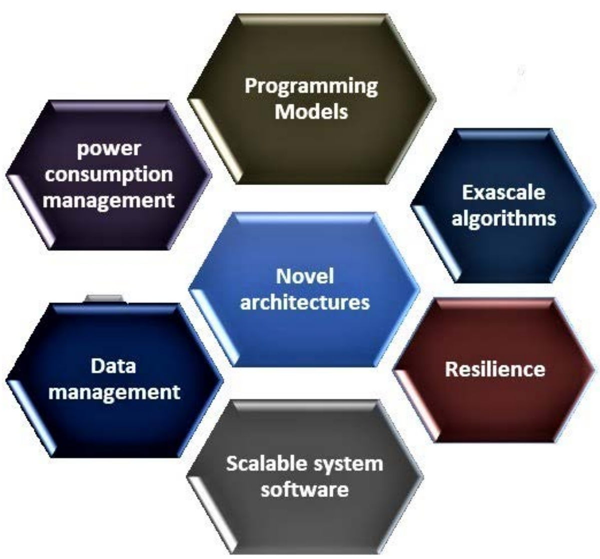

Fig. 2. Challenges of Exascale Supercomputing System.

Exascale systems generally include heaps of nodes drawing excessive Megawatt power, system-wide strategies for power monitoring, controlling, and scheduling. The power consumption of both individual nodes and the overall system is, therefore, an essential issue to cope with [8, 48]. However, new energy-efficient algorithms with novel architecture and devices are needed that can implement the advanced programming models supporting both homogeneous and heterogeneous systems [9, 10, 11].

A considerable number of practical components (computing cores, memory chips, network interfaces) can extensively increase the possibility of partial disasters, load balancing, and reliability issues [3]. Developers cannot be intended to continually cope with load balancing, data management, and reliability issues. The operating system must discover a scalable mechanism that can offer an effective way for load management, memory management, and check-pointing while allowing software developers to complete control over the performance of the system [12, 38].

The objective of the current study is to deal with the two fundamental issues including performance and power consumption HPC Systems. These challenges have a direct relation to the number of resources used. Increase in resources consequently enhance the performance of the system and increase the power consumption as well. The existing programming models and approaches failed to attain such a high level of performance under the constraints defined by the United States Department of Energy [6, 8, 45, 48].

The purpose of this study was to focus on how to enhance the performance of HPC systems with minimum power consumption. Going towards the solution of the problem; we have proposed a Massive Performance and Energy Throttling Framework M2C, for HPC Systems that consumes less power while achieving massive performance efficiently.

The key contributions of this paper can be summarized as follows:

- We have proposed a novel hybrid parallel programming for parallel computing, which is called as MVAPICH2+ CUDA (M2C) model. The proposed M2C model helps to achieve coarse-grained and fine-grained parallelism while parallelizing the data in heterogeneous systems.
- The MVAPICH2 module helps to reduce communication overhead in the heterogeneous system by utilizing the Message Passing Interface (MPI) local handle in the proposed M2C framework and so reduces power consumption.
- The accelerated GPU Computation through CUDA in the M2C model that enables a larger task to run on multiple processors at the same time to enhance the overall performance of the proposed HPC system.

The rest of this paper is structured as follows. In Section 2, we provided an overview of related systems. In Section 3, we described the system model including architecture, flowchart, and algorithm of the proposed M2C framework. In Section 4, we discussed the fundamental HPC metrics which have measured in our experiments. Further Section 5 presents the experimental results, detailed discussion, and comprehensive comparative analysis with existing state-of-the-art methods. Finally, our conclusion follows in Section 6.

II. Related Work

The concept of HPC has been a hot topic in the field of parallel computing for the last two decades. As demonstrated by Moore's law, there has been a rapid evolution of novel hardware and computer architectures to develop parallel computing machines. However, the growth of parallel computing software is not as fast as it should be. One of the reasons for this gap could be the unavailability of desired parallel programming models that support such novel architectures [3]. The traditional models are not capable of delivering such a massive performance as expected in the modern era. Therefore, the demand for novel parallel processing models is increasing day by day which should support homogeneous and heterogeneous systems. Homogeneous cluster systems made up of similar types of cores typically CPUs guarantees the same storage representation. On the other hand, heterogeneous cluster systems usually use more than one kind of processors (or cores) therein CPUs and GPUs are integrated on a single cluster system. If the CPU itself is a multi-core architecture but the cores are different in their capabilities i.e. at least two cores are different in their architecture, such a multi-core architecture is termed heterogeneous multi-core and any embedded system based on it would be termed heterogeneous embedded system. Similarly, an embedded system that has a CPU and a Digital Signal Processor (DSP) is termed heterogeneous embedded system because CPU and DSP are fundamentally different in their architecture. We present an overview of various systems of such types in the following.

A. Message Passing Interface

MPI is the basic library for distributing and communicating the messages among host CPU processors of all the connected nodes [14]. It is used for distributed computing applications and provides an efficient and portable way to address parallel programs. Moreover, to distribute and parallelize data at the inter-node level MPI provides coarse-grained parallelism and maintains synchronization via blocking methods [15]. In the early stages, the basic version MPI-1.0 was originally introduced for distributed memory structures. Later, while evaluating the basic version many modifications were made to enhance the usability of MPI-1.0.

Recently MPI came up with the advanced version MPI-3.1 that include many additional features and functionalities including process groups, process creation & management, environmental management and inquiry, the Info object and point-to-point communication [29, 30].

Throughout the development of HPC, it has been considered as the basic standard for distributing data to multiple nodes and processors. Though MPI designers did not consider the future Exascale systems, it still requires novel MPI configurations and runtime. MPI could be considered a promising model for communicating and passing messages among heterogeneous systems. We have shown the basic structure of how to use the MPI model (see Listing 1).

```
program main
Start
// Starts MPI
 MPI_Init();
// Get no. of processes
 MPI_Comm_size(MPI_COMM_WORLD, size);
// Get current process id
 MPI_Comm_rank(MPI_COMM_WORLD, rank);
// Print Message
 Print ("I am", rank ,"of", size);
// Finalize MPI
 MPI_Finalize ();
 End
```

Listing. 1. Basic Structure of MPI.

B. MPI+OpenMP

The hybrid of MPI and Open Multi-Processing (OMP) is commonly being used for multi-cores distributed homogeneous systems (see Fig. 3) [38]. Data is distributed over multiple nodes and communicated with each other through the MPI scheme. Then it further transferred to the OMP region. OMP determines the available number of threads for that particular node and data written in the OMP region is computed over these threads in shared memory access [16, 17, 18]. MPI is used for inter-node communication to attain coarse grain parallelism whereas OMP is used to achieve fine-grain parallelism over intra-node. In the future, this hybrid approach is one of the promising strategies for dealing with future HPC applications. The latest OMP version is also capable to program GPGPUs for accelerated computing. OMP shared memory multi-processing the programming model is available in C, C++, and FORTRAN for windows and UNIX platforms. This hybrid model is useful for a homogeneous (CPU processors) cluster system [25, 26]. However, it is not preferred for heterogeneous (CPU + GPU) system.

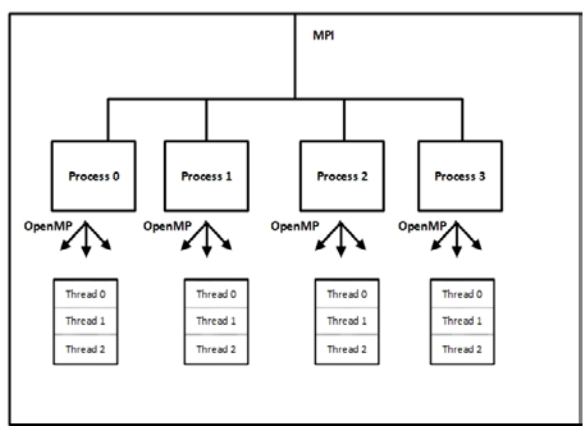

Fig. 3. Processing Mechanism of Hybrid MPI and OMP.

C. Open Computing Language

OpenCL is an efficient parallel programming model for heterogeneous frameworks. OpenCL supports run-time compilation that excludes dependencies on instruction sets, allowing hardware providers to make remarkable changes to instruction sets, drivers, and supporting libraries. It grants portability and compatibility of kernels across multiple hardware and platforms [22, 23]. However, OpenCL requires a complicated setup which includes preparation of settings, command queues, alternatively in addition to a compilation of kernel codes [23].

D. KAUST basic Linear Algebra Subprograms

KBLAS is a diminutive open-source CUDA library that effectively utilizes significant numerical kernels on CUDA-enabled GPUs. It performs a subset of Basic Linear Algebra Subprograms (BLAS) and Linear Algebra PACKage (LAPACK) libraries on NVIDIA GPUs [12, 33]. KBLAS presents a subset of approved BLAS functions. It offers remarkable function along with BLAS-like interface that addresses single as well as multi-GPU systems. Using recursive and batch algorithms, KBLAS maximizes the GPU bandwidth, reuses locally cached data and increases device occupancy. KBLAS's ultimate intent is performance. The collection of KBLAS's tuning parameters have a great impact on its performance regarding Compute Unified Device Architecture (CUDA) runtime version and GPU architecture. While the best performance using the default tuning parameters cannot be promised. Such parameters could be easily edited by users on their local systems. It supports compute capabilities 2.0 (Fermi) or higher. KBLAS is written in CUDA C and requires CUDA Toolkit for installation. In the coming future, KBLAS might be exported with auto-tuners.

E. Compute Unified basic Linear Algebra Subprograms

The CUBLAS library has introduced by Nvidia for its CUDA-enabled GPUs. This library is an implementation of BLAS on the CUDA environment that does not provide ease of parallelizing data automatically across multiple devices. However, this library helps the user to gain access to all the resources provided by Nvidia GPU devices [31, 32, 44]. This API provides the facility to speed up the applications either by scaling up and distributing data across multiple GPUs or by processing expensive tasks on a single GPU configuration. For the best utilization of the CUBLAS library, the application needs to reserve the memory in GPU memory space against each dataset, provides the data to memory, calls the CUBLAS functions in a sequence and then needs to move the data from GPU device back to the host memory [37]. It provides some helper function that assists the user in retrieving and writing data on the GPU memory space. CUBLAS can be used for GPU-accelerated algorithms in various sectors such as image analysis, machine learning and high-performance computing.

F. MOC (MPI + OpenMP + CUDA)

To achieve massive parallelism in parallel computing, a Tri-Hierarchy hybrid MOC (MPI + OpenMP + CUDA) model was proposed in 2018 [20]. This model helped in achieving massive performance through monolithic parallelism when we compute any HPC application over a large-scale cluster system having multiple nodes and a number of GPUs > 2. This model was incorporated of MPI, OpenMP and CUDA where MPI is responsible for broadcasting data over distributed nodes, OpenMP is to run received data in parallel on CPU threads, and CUDA is responsible to execute data over accelerated GPU cores, which is the third level of parallelism [24, 27]. MOC provides massive parallelism by achieving tri-level granularity such as coarse, fine, and finer grain parallelism. Although, it is applicable for heterogeneous single and multiple nodes but preferred to use for a large-scale system.

G. Open Accelerators

OpenACC appeared as a high-level programming model that makes use of high-end and supportive directives programs to achieve parallel computing. The main aim of such directories was to minimize the overhead of modifying the source code and hence enabling the portability to a broad field of computing architecture. It allows single source code to run both on CPU and accelerated GPU devices. So, it supports both homogenous and heterogeneous environments. However, OpenACC does not provide flexibility, thread management, thread synchronization, and optimization for the programs being encountered while achieving massive parallelism [21]. A basic structure of OpenACC has been presented (see Listing 2).

```
Start
#pragma acc data
{
#pragma acc parallel loop …
#pragma acc parallel loop
…
}
End
```

Listing. 2. Basic Structure of OpenACC.

H. MPI + CUDA

A dual hierarchical model, the hybrid of MPI and CUDA is considered to be a promising model for node-level and thread-level optimization. However, the use of more resources decreases system efficiency. In this model, an equal number of CPU processors are used as the number of GPU devices connected to the system. The master MPI processor scatters data to all slave processes. These slave processes help for transferring data from CPU cores to GPU devices. Whenever data is transferred to GPU devices, a kernel is invoked where grid and thread block configurations are mentioned to optimize the resources [19]. After GPU processing completion, data is copied back on host CPU cores and utilized [36]. A general data distributing and processing mechanism through a hybrid of MPI+CUDA have been presented (see Fig. 4). Using the MPI-CUDA hybrid approach, we can call multi kernels to compute different accelerated available devices to achieve finer-grain parallelism. This model could be a leading model for future HPC Exascale Computing System (ECS) applications [38].

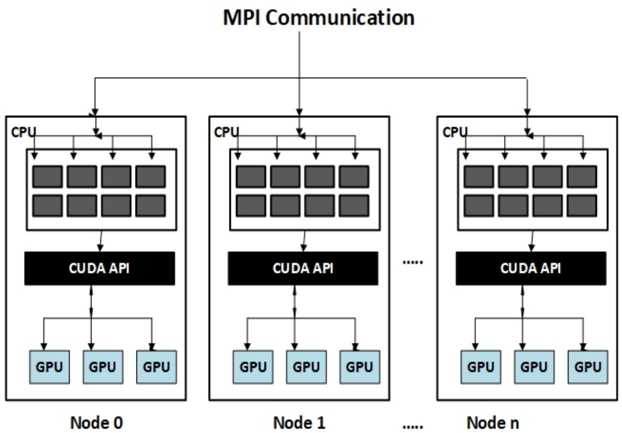

Fig. 4. Processing Mechanism of Hybrid MPI and CUDA.

III. Proposed M2C Model

We have proposed a dual-hybrid model that includes the MVAPICH2+CUDA module (M2C). This massive parallel programming model achieves massive performance by utilizing resources in an efficient manner to reduce power consumption. Following is the elaboration of the proposed M2C model.

A. MVAPICH2

MVAPICH2 is an implementation of the MPI-3.1, which is a thread-safe library developed for high scalability, best performance, and fault tolerance of high-performance computing systems. MPI_Session is a local handle to MPI-3.1 that consumes fewer resources while utilizing the concept of MPI_Group and enabling the scalable communication between different environments [29, 30]. MPI Sessions began as an effort to make aggressive additions/changes to MPI to ensure its success at the Exascale level [38]. It enables better scalability, increases abstraction for better resource isolation, and supports less tightly coupled applications.

It is a new way to initialize (and re-initialize) MPI that uses very few resources by keeping only the state for active communications. It dynamically gathers required data when needed and stores state for the future. It establishes communication relationships/peers before communicating and affect MPI initialization error behavior. The general scheme of MPI_Session has been described (see Fig. 5). MPI Standard 3.1 describes the generic scheme of MPI Session in the following steps [29]:

1) Session initialization and finalization: The compiler creates the session when the constructor for MPI_Session is called and destroys the session when its matching destructor is called. It has elaborated on how these functions initialize and finalize the session (see Listing 3).

```
int MPI_Session_init (
      MPI_Info process_info,
      MPI_Errhandler err,
      MPI_Session *sessionName);

int MPI_Session_Finalize (
MPI_Session *sessionName);
```

Listing. 3. Session Constructor and Destructor.

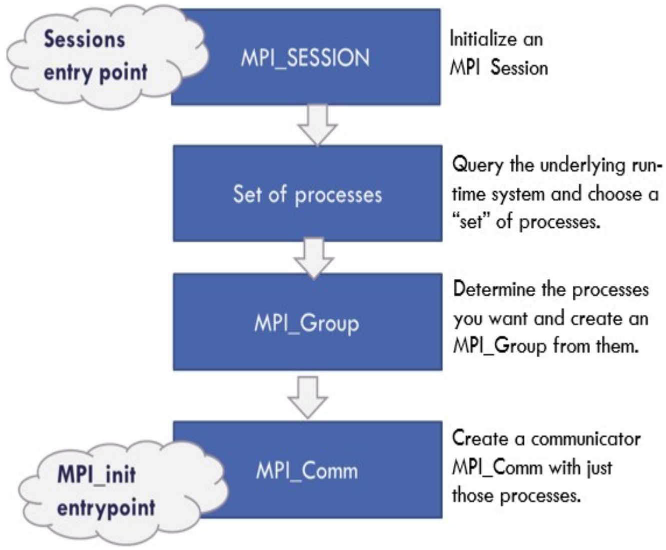

Fig. 5. Overview of the MPI_SESSION.

The working of a new session is initialized whenever MPI_Session_init() function is called by passing certain parameters to it, which returns a valid handle i.e. sessionName of the recently created session. The parameter 'err' is passed to this function which controls the MPI's error handling response during the creation of the session. One more parameter 'process_info' is passed which provides the information to the user that can be helpful for MPI to manage the session's creation. For destroying a session, the function MPI_Session_finalize() is used, which ensures that session no more exists by setting the session handle i.e. sessionName to MPI_SESSION_NULL.

2) Querying runtime system for named sets: MPI processes use the concept of 'named set' for querying the runtime system to retrieve the named sets of processes to utilize them for creating the corresponding MPI_Group against each named set. The function MPI_Session get_names() is used to retrieve all set's names from the runtime has been listed (see Listing 4).

```
int MPI_Session_get_names (
 MPI_Session sessionName,
 char **setName);
```

Listing. 4. Querying Runtime System for Named Sets.

MPI allocates space for the array of strings in the memory (which we termed as 'setName' in Listing 4) when the session is created and freed the space on the session destruction.

3) Getting the size of set from runtime: Information regarding a specific named set is exposed by the runtime using function MPI_Session_get_info() has been prototyped (see Listing 5). It provides an object called 'MPI_Info' which returns the 'size'. The value of this size actually provides the information about each set i.e. the total number of processes in each set. By using this information against each set provided by the runtime, a user can easily decide which groups have to be created for gaining access to the exact required resources.

```
int MPI_Session_get_info (
 MPI_Session sessionName,
 char *setName,
 MPI_Info *size);
```

Listing. 5. Getting Size of Named Set from the Runtime via a Session.

4) Converting set to group: The function MPI_Group_create_session() is used to convert each named set to the group by using the information of each set as elaborated in Step 2 and Step 3 (see Listing 6). This group can then be used for making the communicator for a group of processes. MPI_Group helps to maintain the meta-data of all the available resources stored by the runtime in a scalable manner. If the information of sets stored by runtime internally is scalable, then the internal representation of the corresponding group can also be scalable [28]. Operations that create a group 'non-scalable' must be avoided in order to achieve good scalability.

```
int MPI_Group_create_session (
 MPI_Session session,
 char *name,
 MPI_Group *group);
```

Listing. 6. Converting Named set to Group via a Session.

5) Assigning Communicator to each group: For creating a communicator against each group, the MPI library introduces MPI_Comm_create_group_X() function (see Listing 7). In MPI, to initiate the communication, a parent communicator (MPI_COMM_WORLD) is used generally containing the information of all the processes. This parent communicator consumes countless resources by storing the information of processes even not to be used by the communicator in the communication process. This new concept of creating a communicator via a session provides the facility of assigning a single communicator to each group by providing the same functionality without even using a parent communicator [29].

```
int MPI_Comm_create_group_X (
 MPI_Group myGroup,
 char *tagID,
 MPI_Info size,
 MPI_Errhandler err,
 MPI_Comm *mycomm);
```

Listing. 7. Assigning a Communicator to a Group.

The parameter "myGroup" is passed to the function to provide the specific group of processes to the communicator. The parameter "mycomm" is used to return the new communicator for the targeted group. Other parameters i.e. "size" and "err" are passed to the function that will provide the additional information, which is what is usually not provided by MPI for this communicator creation function. The 'size' parameter is used to query the exact number of processes for which the group has been made and the corresponding communicator is going to be created. The "err" parameter is added to the communicator function that will catch error in case of any failure throughout the session creation.

B. Accelerated Graphics Processing Unit Computation

CUDA is an efficient parallel programming model utilizing accelerated GPUs and threads for massive parallelism [23]. CUDA refers to as the most competent model for thread-level optimization that allows application flexibility by supporting heterogeneous computation where the application uses both the CPU and GPU devices. CUDA parallel programming utilizes the 'CUDA Kernel' to parallelize the data on GPU devices. According to the novel architecture of CUDA GPUs, a block dispatcher has introduced that assign one self-synchronized thread per computational core to schedule the grid. Shared memory is assigned to each block and all the cores within the block can have access to this shared memory [19, 24, 27]. Threads use this shared memory to process the data of a certain block and return the processed data to the GPU block scheduler. The scheduler stores the processed data to GPU global memory space accessible to all the CPU cores of the host. The CPU cores in response read the data from GPU memory and transfer it to CPU cores and then to the main memory. Using this mechanism, CUDA helps to achieve massive parallelism by utilizing both the CPU and GPU devices. The basic structure of using CUDA in C++ has been demonstrated (see Listing 8).

```
Begin
float *a_cpu,*a_gpu;
cudaMalloc ((void **) &a_d, size);
cudaMemcpy (a_gpu, a_cpu, cudaMemcpyHostToDevice);
kernel_function <<< n_blocks, block_size >>> (params);
cudaMemcpy (a_gpu, a_cpu, cudaMemcpyHostToDevice);
cudaFree(a_gpu);
End
    // Cuda kernel to run on GPU
__global__ void kernel_function (params)
    {
    Statements;
    }
```

Listing. 8. Basic Structure of CUDA.

C. M2C Framework

We have shown the architecture of our proposed model M2C (see Fig. 6). Therein, the dual-hierarchy model of MVAPICH2 and CUDA is incorporated. MVAPICH2 is responsible for broadcasting data over distributed nodes while CUDA is responsible to run the code on GPU. The HPC cluster system is made up of multiple racks having thousands of nodes that perform extensive calculations and computations simultaneously.

A detailed workflow of the dual-level hybrid model has been shown in which we have shown the steps of how the proposed model works for a single node in the HPC cluster environment (see Fig. 7). We have considered the DMM application developed in the C++ language to interact with MVAPICH2. The basic functionality of the proposed model is embedded in the concerned user application. This user application receives input data from MPI to solve the extensive computational problem. In the MVAPICH2 communication world, the problem is divided into subproblems by providing coarse-grained parallelism. MPI master process further scatters these subproblems to multiple slave processes and data is transformed from CPU to GPU environment. GPU environment performs CUDA computation on the received data by invoking the CUDA kernels.

The subproblems are divided into multiple chunks/statements and are parallelized to multiple processors and thousands of cores by providing fine-grained parallelism. The thousands of accelerated cores work simultaneously on a single problem and solve the extensive problem by utilizing both coarse-grained and fine-grained parallelism. Once the data processing is completed, the resultant data is returned in a similar way where processed data is transferred from GPU to CPU cores and so CPU cores return data to the MPI master process. Then the reserved memory for CPUs and GPUs is released.

A quick overview of how MVAPICH2 and CUDA in the M2C model take part to provide massive parallelism. A detailed algorithm for the basic Dense Matrix Multiplication (DMM) application has been presented (see Listing 9). In our proposed model, some significant specifications i.e. the total number of nodes, number of CPUs per node, number of GPU devices per node, number of cores per CPU, and memory levels of the system are obtained in an initial phase. These specifications help the programmer to acknowledge the best resources for the proposed model. However, the rest of the workflow of this proposed algorithm is elaborated as follows:

- Initialize session and getting set names and size of processes (line 2-4): MPI Session in the proposed model is a local handle to MPI-3.1, used to provide the coarse-grained parallelism by passing the data to slave processes. MPI Session query the runtime to obtain the active processes. By using this information provided by the runtime, a user can easily decide which groups of processes have to be created for gaining access to the exact required resources.
- Converting sets to groups, assigning communicators, and getting rank of processes (line 5-7): A communicator is assigned to each group that helps to communicate between the processes. Some additional necessary functions are called that return the information of the sets and groups, size, and rank of the active processes.
- Send and Receive data according to the ranks of processes (line 8-15): Following the ranks, '0' ranks are defined as a master rank process and rest of all are considered as slave processes. In the case of master rank, data is broadcasted over all other ranked processes through appropriate methods. Generally, MPI_Send() and MPI_Recv() are used for synchronous (blocking) whereas MPI_Isend and MPI_Irecv() are used for asynchronous (non-blocking) processing. The current study deals with different HPC applications instead of any specific application, in such case, normally programmer is not sure about data dependency then asynchronous processing may not perform better.

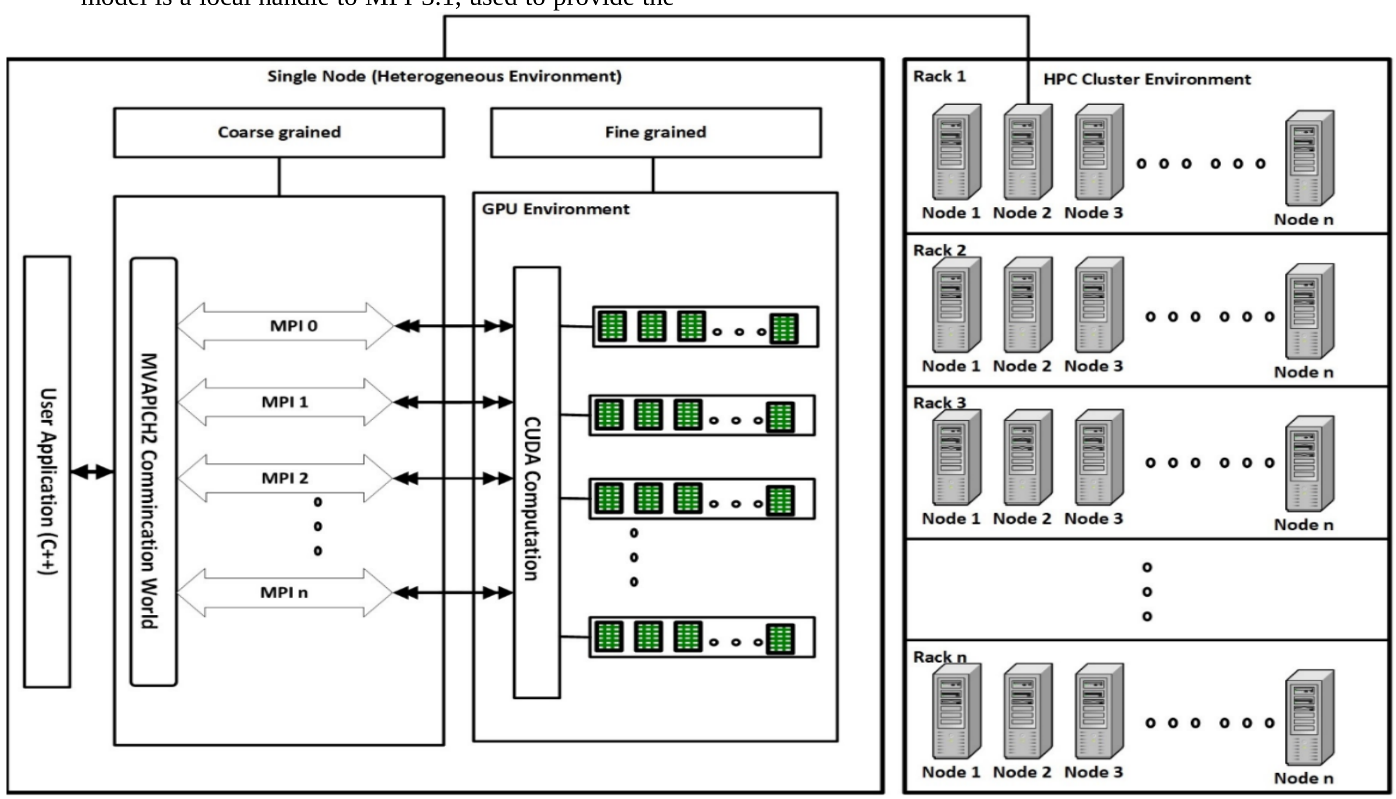

Fig. 6. Architecture of Proposed M2C Model.

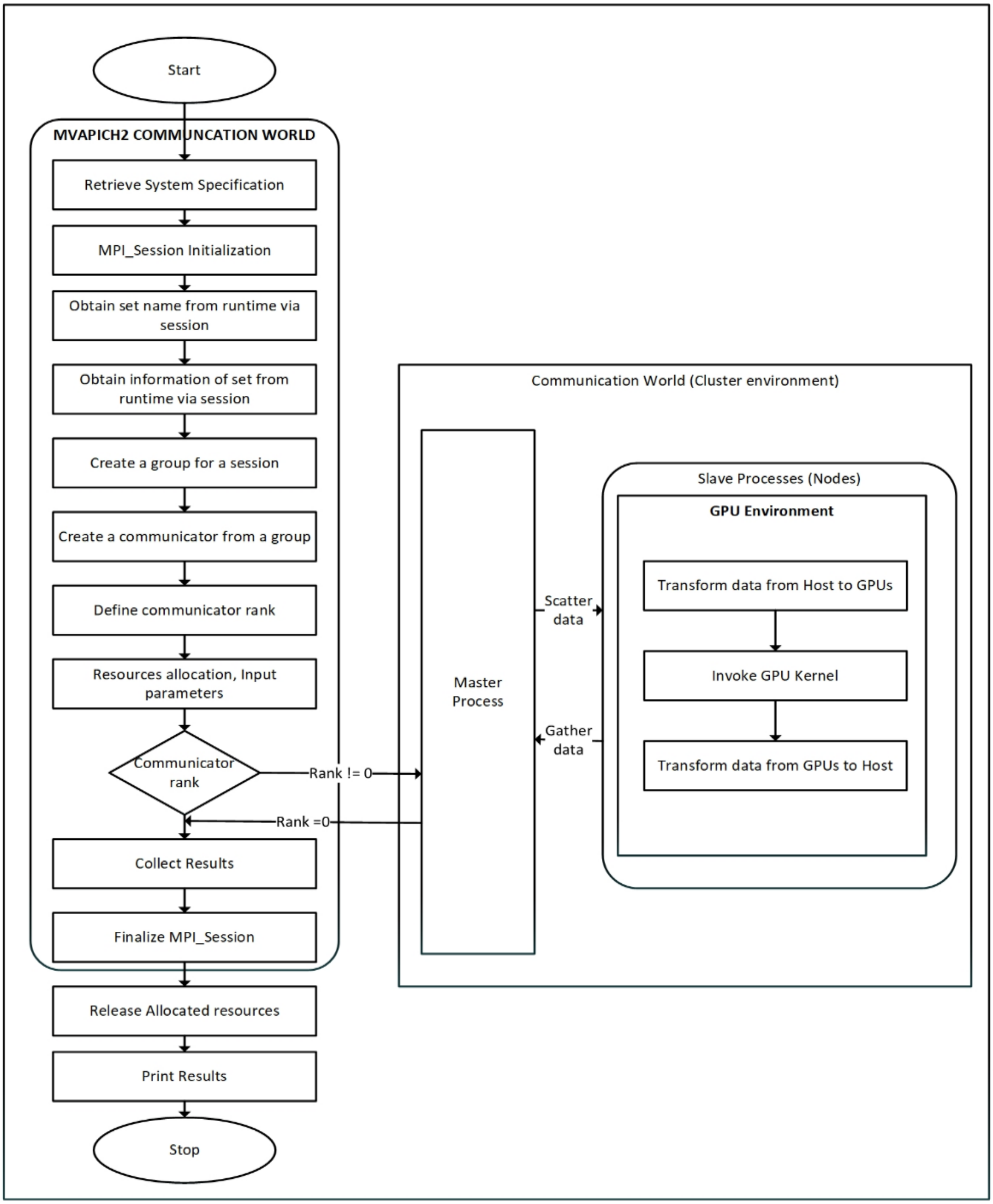

Fig. 7. Workflow of Proposed M2C Model.

```
Input:   mA Input Matrix
 mB Input Matrix
Output: mC Resulting Matrix
Declarations: SessionName, SetName, Size,
GroupName, Comm, Rank, i, numDev, A_D, C_D.
1.  Start MVAPICH2 Parallel Region
2.  SessionName MPI_Session_init()// Initialize MPI session
3.  SetName MPI_Session_get_names()// Group of processes = Set, obtaining set name from runtime via session
4.  Size MPI_Session_get_info()// Get Communication size
5.  GroupName MPI_Group_create_session()// Convert SetName into GroupName.
6.  Comm MPI_Comm_create_group_X()// Group Communicator
7.  Rank MPI_Comm_rank()// Get MPI Ranks
8.  If Rank == Master // define master rank if rank (0)
9.  Make local initialization.
10. Else
11. MPI_Isend() // Send data to all processes Rank>0
12. End If – Else
13. If Rank > 0 // If rank is slave but not master process
14. MPI_Irecv() // Receive data from all slave processes
15. End If
16. Start CUDA Parallel Region
17. While (i<numDev) Do // Until Number of GPU devices
 // Assign a device id to specific GPU device
18.  cudaSetdevice(devID)
 // Copy data from host to NIVIDIA GPU Devices
19.  cudaMemcpy() A_D mA
20.  InvokeCUDAKernel << grdSize,blkSiz, >>> (A_D, A_B,A_C)
 // Copy data from GPU Devices to host.
21.  cudaMemcpy() mC C_D
22. Free all device variables
23. End CUDA Parallel Region
24. // There is MPI master process
25. If Rank == 0
     // Receive processed data from all rank
26. MPI_Irecv()
27. End If
     // Finalize MVAPICH2 processing
28. MPI_Session_finalize()
29. End MVAPICH2 Processing/Parallel Region
     // Return the results
30. Return mC
```

Listing. 9. The Dual-Hybrid M2C Model.

However, we implemented a synchronous (blocking) strategy for all MPI based models in the current study. This data distribution mechanism requires fewer resources (i.e. get the information of only the active processes) and hence consume less power while implementation and provides coarse grain parallelism in the system [48].

Start CUDA parallel region and receive processed data (line 16-20): Once data is distributed over all connected nodes in the targeted system, the data is computed over accelerated GPU devices. For this purpose, CUDA statements are defined and kernels are invoked for GPU computation.

Finalize MPI Session, return results and End MVAPICH2 parallel region (line 26-30): Once the whole data processing is completed, the resultant data is returned in the similar way where processed data is transferred from GPU to CPU cores then CPU cores return data to MPI master process and reserved memory for CPUs and GPUs is released.

IV. Performance Analysis

In this section, we investigate the performance of the proposed M2C system. In this regard, our experiments related suggested dual-level hybrid model M2C were carried out on Aziz-supercomputer manufactured by Fujitsu of HPC Centre of King Abdul-Aziz University, Jeddah, Saudi Arabia [40, 41, 42].

A. Platform of Experiment

The platform of our experiment, Aziz-Fujitsu Primergy CX400 Intel Xeon True-scale QDR supercomputer, was ranked at 360th position in the list of top- 500 supercomputers in 2015 [39]. This Aziz-supercomputer contains 380 thin (regular) and 112 fat (large) computing nodes with a total of 492 computing nodes that interlinked through the InfiniBand within the racks. Recently Aziz supercomputer was upgraded from homogeneous to the heterogeneous system according to the growing need of massively parallel computing by adding two NVIDIA Tesla K20 GPUs based on SMID architecture of 2496 CUDA-cores per device. Two Intel Xeon Phi Coprocessor (MIC) containing 60 integrated cores per processor were also introduced into Aziz-supercomputer to upgrade the system. The heterogeneous system of Aziz supercomputer has total 11904 number of cores [39, 40, 41, 42]. Therein, the memory of a regular computing node and a large node is 96GB and 256GB, respectively. Each node consisting of Intel E5- 2695v2 processor with 12 physical cores with 2.4GHz processing power, which is what is operated by Cent Operating System-v6.4. CUDA toolkit version-9.1 is installed along with other compilers essential for accelerated programming in HPC libraries. MVAPICH2-GDR 2.3.1 is used to enable MPI with the support of accelerated GPU devices. All the accelerated devices and computing nodes of the supercomputer are connected by InfiniBand, User, and Management networks. InfiniBand is used to parallelize the file system, while the user network is used for login and job submission handling. Management and controlling operations are usually supported by the management network only. According to the LINPACK benchmark and theoretical peak performance, the performance of Aziz supercomputer was marked as 211.3 TFlops/sec and 228.5 TFlops/sec, respectively.

B. HPC Metrics

We have taken different metrics including total time for execution, total number of Flops measured, energy efficiency, and overall power consumption of the system. These metrics can be categorized into the following two fundamentals metrics.

1) Performance Measurement: The overall performance of HPC system is considered as the most fundamental and essential metric in massive parallel programming which is measured in a total number of achieved floating-point operations per second (Flops) [32]. The total number of achieved Flops (F_T) can be calculated by dividing the achieved Flops calculated at the peak performance of the system (F_{pp}) by the total execution time (T_{Exec}) [20], which can be written as follows:

$$F_T = \frac{F_{pp}}{T_{Exec}} \tag{1}$$

We have calculated the number of Flops (F_T) based on execution time by implementing the M2C model on DMM application against varying datasets by considering the peak performance of Aziz-supercomputer i.e. 211.3 TFlops /s, [47].

2) Power Measurement: In emerging supercomputers, energy efficiency with less power consumption is of interest [6, 8, 46]. In this regard, we have used well-known software applications of Open Hardware Monitor [34] and GPU-Z.2.6.0 [35] for the measurement of CPU and GPU temperature and power consumption, respectively. We have shown the running states of Open Hardware Monitor and GPU-Z.2.6.0 (see Appendix 1 and Appendix 2, respectively). The total energy consumed by a system Esys can be calculated by integrating the energy consumption composed of memory contention, bandwidth, parallelism and behavior of the application [20] as follows:

$$E_{sys} = \int_0^t memC\ (dt) + bandW\ (dt) + Parll\ (dt) + Bhv\ (dt) \tag{2}$$

As discussed earlier, the future Exascale supercomputing system will be a heterogeneous architectural system. This is how necessary to emphasize primarily on power consumption for both homogeneous and heterogeneous architectural based systems. The power consumption in a heterogeneous system is considered into three major parts including power consumption by host CPU processors, power consumption by memory operations (inter-memory and intra-memory) and power consumption by accelerated GPU devices. Power consumption for the systems having GPU installed on it is calculated by [20] as follows,

$$P_{sys}(w) = \sum_{i=1}^{N} P_{GPU}^{i}\ (w^i) + P_{CPU} \sum_{j}^{M}(w^j) + P_{main}(w) \tag{3}$$

where, P_{cpu}, P_{gpu}, P_{sys}, P_{main} indicate power of the CPU, GPU, system and motherboard, respectively. N and M denote the number of GPUs and the total CPU threads in the system, respectively. w_i and w_j account for the workload of GPU i and CPU j, respectively.

The power consumption on a specific application (P_{app}) of the system can be calculated as follows [20],

$$P_{app}(w) = \sum_{i=1}^{N_{app}} P_{GPU}^{i}\ (w^i) + P_{CPU} \sum_{j}^{M}(w^j) + P_{main}\left(w_{app}\right) \tag{4}$$

Where P_{app} is proportional to the workload of the system.

V. Results and Discussion

We have investigated our M2C model by implementing it into the Dense Matrix Multiplication (DMM) application on Aziz-supercomputer for emerging Exascale systems that provide tremendous performance through massive parallelism and limiting the overall power consumption. Therein, two fundamental HPC metrics i.e. performance and power consumption were observed during the experiments. All results have been executed using four kernels for GPU processing of supercomputers. The quantified metrics were observed for different matrix sizes. The performance in linear DMM application was observed against different datasets by determining the floating-point operations in GFlops/sec while the power consumption was calculated for different matrix sizes in GFlops/ Watt. We quantified different metrics including performance and power consumption. We measured the fundamental parameters including time execution, speedup, and number of flops whereas power consumption related metrics were including as power consumption and temperature.

We have implemented three well-known libraries named MOC, kBLAS, and cuBLAS [49, 50] in DMM application for the same HPC metrics taken on Aziz-supercomputer. For datasets 1000-10000, kBLAS and cuBLAS were able to achieve their peak performances as 830 and 690 GFlops/sec, respectively. We observe that MOC outperformed all the three implemented models by delivering peak performance up to 1TFlops. The results against each dataset for MOC, kBLAS, and cuBLAS were compared with that of the proposed M2C model.

Our proposed model outperforms all the other implemented models for datasets 1000-10000 by delivering peak performance even more than that of the MOC model with 1.27 TFlops (see Fig. 8).

Similarly, the energy efficiency by all of the implemented algorithms was observed, therein cuBLAS, kBLAS and MOC achieved 5.2, 5.6 and 6 number of GFlops/Watt for small matrix size, respectively. For the same small matrix size, the proposed M2C model attains 7.099 number of GFlops/Watt. It is noticed that cuBLAS, kBLAS and MOC models attain the maximum number of GFlops/Watt as 6.2, 6.5 and 8, respectively. On the other hand, M2C delivered 8 GFlops/Watt in initial matrix size and by increasing the matrix size the energy efficiency also increased and reached up to a maximum of 10.38 GFlops/Watt for the large matrix size (see Fig. 9).

We observe that our M2C model delivered better performance in 1Watt compared to that of the other implemented models. In M2C the framework, the idea of MPI_Session and MPI_Group has worked well for limiting power consumption. MPI_Session a local handle of MPI-3.1 i.e. MVAPICH2 uses very few resources by keeping only the state for active communications. So, it helps to reduce communication in the heterogeneous system. This parent communicator consumes countless resources by storing the information of processes even not to be used by the communicator in the communication process. The new concept of creating a communicator via a session provides the facility of assigning a single communicator to each group (created via MPI_Group) to provide the same functionality without even using a parent communicator.

MVAPICH2 by consuming fewer resources and reducing communication over-head has helped us to limit the power consumption and provided remarkable performance in 1Watt compared to that in kBLAS, cuBLAS, and MOC models. This could be helpful to notice that performance and power consumption are directly related to each other. However, there exists a trade-off between these two metrics which can be determined as follows:

$$\frac{Performance}{Power} = \frac{Execution\ within\ the\ time\ unit}{Energy\ during\ the\ execution\ time\ unit} \quad (5)$$

where the rate of change of performance under specific power consumption measured in Glops and GFlops/Watt, respectively.

The comparative analysis of tradeoff for cuBLAS, kBLAS, MOC and M2C models (see Fig. 10). The vertical and horizontal lines respectively represent performance and power consumption. We can notice that cuBLAS, kBLAS and MOC libraries performed well in the DMM algorithm. However, the proposed model M2C outperformed all the implemented models by accomplishing 1278 GFlops and by consuming 123W total power during larger matrix multiplication.

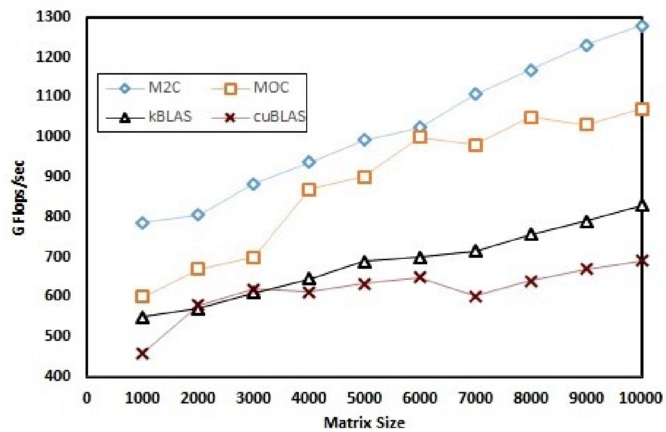

Fig. 8. M2C Performance Comparison with MOC, kBLAS and cuBLAS.

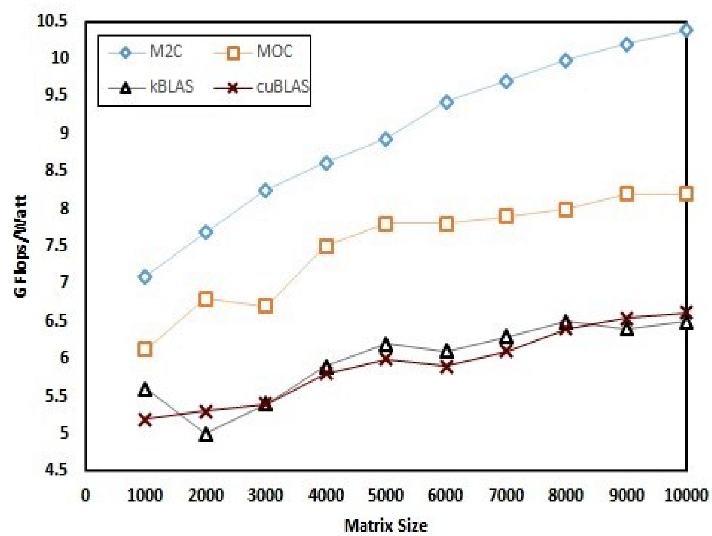

Fig. 9. Energy Efficiency in DMM for M2C vs (MOC, kBLAS & cuBLAS).

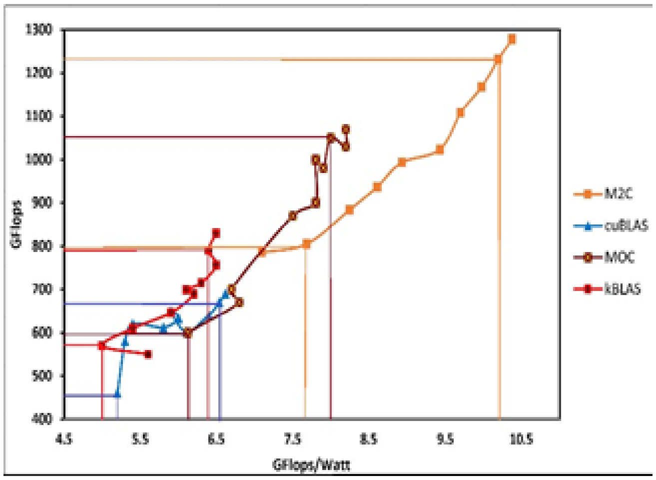

Fig. 10. Performance-Energy Efficiency Tradeoff.

Hence, our proposed system could be envisioned as a promising model for achieving massive performance in emerging Exascale systems. In this regard, the most challenging step towards Exascale computing systems is that it does not exist yet. However, the performance of HPC systems has been improved based on the current results and predictions to achieve Exascale performance. The fundamental challenges mentioned in this paper would require targeted investments to acquire Exascale computing. The primary goal of Exascale computing systems is to handle massive data HPC applications. Performance and power consumption are the two primary HPC metrics that have been taken into consideration the most challenging factors for Exascale computing systems. These challenges have a direct relationship with the number of resources. An increase in the number of resources consequently enhance the performance in the system and so increase the power consumption as well.

VI. Conclusion

Towards the race of achieving Exascale performance, power consumption has been the most significantly constrained resource among all the others. Therefore, achieving practical Exascale computing with optimum performance is of interest. In this regard, an advanced computing system can deliver a thousand-fold performance improvement compared to the current Petascale computing. However, new system-wide methodologies and methods for power monitoring and administration are somewhat necessary. Novel programming models and programming methodologies are undergone rapid growth, but the quest for enhanced programming models always exists. There are significant questions and research regarding the models that will be used at the Exascale level to achieve better performance than the current Petascale systems. Contributing to the quest for the optimum programming model for Exascale systems, a novel parallel programming model named M2C has been proposed. The proposed model has been evaluated by implementing linear DMM application on heterogeneous architecture and the results have been compared with well-known libraries such as MOC, kBLAS, and cuBLAS. M2C results using 4 kernels for GPU processing outperformed all the other implemented models while achieving 1278 GFlops by consuming 123W total power. Nevertheless, the proposed M2C model could be a promising and leading model for emerging Exascale systems.

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Systematic Review Study of Decision Trees based Software Development Effort Estimation

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***Abstract*—The role of decision trees in software development effort estimation (SDEE) has received increased attention across several disciplines in recent years thanks to their power of predicting, their ease of use, and understanding. Furthermore, there are a large number of published studies that investigated the use of a decision tree (DT) techniques in SDEE. Nevertheless, in reviewing the literature, a systematic literature review (SLR) that assesses the evidence stated on DT techniques is still lacking. The main issues addressed in this paper have been divided into five parts: prediction accuracy, performance comparison, suitable conditions of prediction, the effect of the methods employed in association with DT techniques, and DT tools. To carry out this SLR, we performed an automatic search over five digital libraries for studies published between 1985 and 2019. In general, the results of this SLR revealed that most DT methods outperform many techniques and show an improvement in accuracy when combined with association rules (AR), fuzzy logic (FL), and bagging. Additionally, it has been observed a limited use of DT tools: it is therefore suggested for researchers to develop more DT tools to promote the industrial utilization of DT amongst professionals.**

Keywords*—Systematic literature review; decision tree; regression tree; software development effort estimation

I. Introduction

Much of the greater part of the literature on software project management pays particular attention to SDEE. According to [1] SDEE refers to the process of estimating the necessary effort needed for developing any software with regards to money, timeline, and staffing. The effort's unit is generally expressed in man-day/month/hour [2]. For instance, precise and accurate software cost prediction can result in successful control of the budget, time, and appropriate resource allocation. Unfortunately, overestimating is almost as strong a risk factor for software project failure as underestimating. Similarly, [3] found that inaccurate estimates of required resources are one of the most common reasons why software projects fail. Making correct estimation, therefore, helps in analyzing the practicability of any project regarding its cost-effectiveness [4] which ensures its success.

To date, there is a notable amount of studies investigating new models to perform accurate SDEE. In the SLR made by [5] over 304 candidate journal studies, they have outlined 11 prediction techniques which are grouped into two main groups: 1) algorithmic effort modeling which predict costs using a mathematical formula of project's attributes, 2) Machine learning techniques like (decision tree (DT), artificial neural networks (ANN), genetic programming (GA), and case-based reasoning (CBR)). Generally, machine learning techniques (MaL) have received considerable attention thanks to their power of modeling complex relations between software attributes and the target value (software cost), extremely where the form of the relationship cannot be straightforwardly determined. In the same vein, [6] has also conducted an SLR where they listed eight types of machine learning models. Overall, the results indicate that ANN, analogy based estimation (ABE), and DT are the most commonly employed SDEE techniques with (37%, 26%, and 17% respectively). A similar decreasing order is reported in [5]. Furthermore, DTs were adopted for SDEE mostly for their capability of predicting and interpreting results, unlike other MaL techniques as claimed by [7] in their systematic mapping study of decision tree-based SDEE where they identify 46 relevant papers. However, there exist some strong conditions and limitations that affect the ease use of DT techniques in a specific context (see Section III.C).

Also, results from earlier studies demonstrate a strong and inconsistent accuracy of DT, as compared to MaL and Non-MaL cost estimation techniques. According to some papers [8][9][10], DT outperforms regression models. This outcome is contrary to that of [11][12][13] who have highlighted the relevance of regression models in providing more accurate estimates than DT models. Moreover, DT show superior accuracy than RBFN models as reported in [14][15][16][17] differs from the findings presented in some published studies [17][18]. These existing inconsistent results have heightened the need for reviewing the evidence of the DT model, to better understand and enhance their application.

Furthermore, in reviewing the literature, it should be noted that there is no SLR of DTs for software effort estimation. Thereby, we follow the methodology presented by [19] in order to make a concise selection, deep examination, and synthesizing findings of all DT studies made from 1985 until 2019. This study examines the evidence of DT models concerning the following five perspectives: (1) the prediction accuracy of DT methods; (2) the comparison of prediction accuracy of DT techniques and other methods; (3) the suitable estimation contexts for employing DT techniques; (4) the effect of combining other methods with DT models; and (5) tools that implement DT methods.

The organization of this study is as follows. Section II outlines the methodology of research used to perform this SLR. Section III describes and analyzes distinct review results; Section IV summarizes the fundamental finding and suggests some recommendations for research and practice. Section V reports this review's limitations. Finally, Section VI presents conclusions and gives the perceptiveness of future work.

II. Methodology

The main steps of this SLR are: determining review questions, explicating the strategy of research, making a study selection, performing a quality assessment, extracting, and synthesizing data. All these steps will be detailed in the subsequent subsections.

A. Review Questions (ReQs)

This SLR attempts to assess the evidence of DT methods and to perform favorable recommendations based on the certainty of results. The five review questions are as follows:

ReQ1: How is globally the prediction accuracy of DT methods?

ReQ2: What is the performance of DT methods in comparison with other methods (MaL or Non-MaL)?

ReQ3: What are the suitable conditions for an accurate estimation of DT techniques?

ReQ4: How does the combination of other techniques with DT techniques affect the estimation accuracy?

ReQ5: What are the most commonly used DT tools?

B. Search Strategy

The search strategy encloses three phases that help at answering the ReQs, which are outlined precisely thereafter.

1) Search string: We construct the search string from words derived from ReQs and also by searching their homonyms, along with employing AND, OR, and NEAR operators to restrain the research results. We use the same search string conceived by Najm et al. [7].

2) Literature resources: To seek relevant studies, we use the next five electronic databases considering that they are largely employed in review studies: IEEE Xplore, Science Direct, ACM Digital Library, Springer, and DBLP.

3) Search process: The search process is handled out in two stages: in the first stage we search in digital databases for a query string to select relevant studies, the inspection takes into account the abstract, the document's title, keywords/Index as well as the whole text to not miss any suitable paper, after that the second stage consists of looking for additional papers by examining references of predetermined articles (selected in the 1st stage).

C. Study Selection

The study selection aims at identifying appropriate articles that address ReQs. So, to achieve this purpose, we use the inclusion/exclusion criteria to choose or discard the papers.

We notice that we employ the similar inclusion/exclusion criteria used by Najm et al. [7].

Fig. 1 shows the total of selected or remained papers after each phase, while phases are marked by letters from a to f.

D. Quality Assessment

Quality assessment (QuA) was conducted in this review to prevent any biased information that can affect the findings. For this purpose, the quality of 50 extracted papers was evaluated using the six following questions:

QuA1: Does the paper define explicitly the intended goals of the study?

QuA2: Does the study present properly the solution proposed?

QuA3: There exists a clear explanation of the estimate's context?

QuA4: There exist some supporting studies reported in the paper?

QuA5: Does the paper make any significant contribution to academia/industry?

QuA6: What is the quality of the publication channel where the articles were published?

Concerning questions 1-5, they can accept three answers as follows: ''Yes", ''Partially", and ''No", which have the corresponding scores: (+1), (+0.5), and (0).

While question 6 was scored based on the rates provided in Scimago Journal Rank (SJR) and Conference Rankings (CORE) [20]. It accepts these answers:

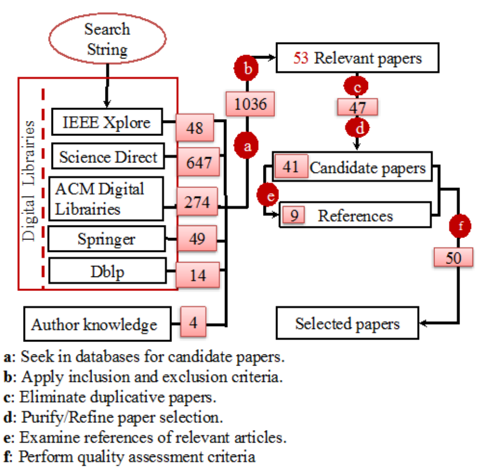

Fig. 1. Search, Selection and QuA Process.

Journals: (+1) for journals ranked Q1, (+0.5) for journals ranked Q2, and (0) for journals ranked Q3 or Q4.

Conferences/workshops/symposiums: (+1) for conferences/workshops/symposiums ranked CORE A, (+0.5) for the conferences/workshops/symposiums ranked CORE B, and (0) for conferences/workshops/symposiums ranked CORE C.

Although the QuA criteria, as well as their rates, might be nonobjective, they help us to compare the chosen studies. We note that the same criteria were employed in [6][21]. The quality assessment was conducted separately by two researchers who answer carefully the answers; any discord was discussed and finally, fixed by mutual agreement between the two researchers. We then selected only papers whose score rise above 3 (50% of the excellent quality of a paper: 6). All 50 relevant papers were then selected due to their suitable quality score of more than 3.

E. Data Extraction and Synthesis

The data extraction is used to extract all relevant data from selected papers to answer ReQs. Table I shows the form of data extraction.

To deal with the research question posed in this review study, two researchers read separately and synthesize carefully the selected papers, there were some disagreements concerning some review questions. Though, any discord was discussed and finally resolved by mutual agreement between the two researchers. It is worth noting, that for some review questions such as ReQ1, ReQ2, and ReQ4 the data was not obtained directly. We followed the same solution reported in [6]. Therefore, for the studies using multiple configurations, only the value relative to the best performance was extracted. While for studies using different database sampling, we used the mean of the accuracy value.

To address the review questions, the next step after the data extraction is the data synthesis, which aims to promote and enhance the generalization of the result. Yet, various methods were adopted:

- Narrative synthesis: It consists of enumerating the data and summarizing the finding of studies. We use tables, bar charts, and boxplots to strengthen the visualization of results.
- Vote counting: It intends to sum up the number of cases where a model outperforms or underperforms other models. It was used to address ReQs (ReQ2).
- Reciprocal translation: It consists of a translation of notions listed in the selected studies to determine similarities and recognize a difference between them. It was used to address the review question ReQ3.

TABLE I. DATA EXTRACTION FORM

Data extractor
Data checker
Study identifier
Name(s) of the author(s)
Article title
Author(s) purposes
ReQ1 – Estimation accuracy criteria and methods used to assess DT techniques
ReQ2 – Performance of DT techniques in comparison with other methods
ReQ3 – The suitable conditions for an accurate estimation of DT techniques
ReQ4 – Effects of combining DT techniques with other models
ReQ5 – The most commonly used DT tools

III. REVIEW RESULTS

In this section, we report and analyze the findings of all ReQs. A deep discussion and interpretation of the finding will be addressed in the following subsections.

A. Estimation Accuracy of DT Techniques (ReQ1)

The majority of studies are based on a history-based type, which means that the evaluation of DT techniques is based on historical software project datasets. Consequently, the accuracy of these DT estimation techniques may depend on certain categories of parameters which are organized into three different groups: the first concerns the dataset's characteristics like (dimension, outliers and missed data, etc); the second is about the DT's structure (Split rule, number of cases per node, depth of the tree, stopping criteria, effort calculation method, etc); the third concerns the employed techniques of evaluation and validation such as (assessment measures, k-fold, the leave-one-out method, etc.).

Additionally, it has been observed in the 50 selected studies that several datasets were applied to form and to assess the performance of DT models (see Fig. 2).

Table II shows the most commonly used databases mainly those employed in more than four studies, along with the proportion, the number of papers that employ each database, and the totality of projects per number of studies. What can be seen in Table II is the high rate of usage of the ISBSG dataset (20%), and then the COCOMO (13%) followed by Desharnais and NASA with (11% and 8% respectively).

Besides, several evaluation techniques were used to assess the prediction accuracy of DT models. The three techniques mostly used were holdout, leave-one-out (LOO), and k-fold (k>1). The Holdout was largely used about (72% or 28 of papers), followed by k-fold cross-validation (36% or 14 of studies), and LOOCV (21% or 8 of studies), we note that the total number of percentage exceeds 100% since some papers use more than one evaluation method.

Regarding the accuracy criteria, the selected studies use several measures; especially the MMRE is employed in 31 papers (63%), Pred(25) is employed in 29 papers (59%), and MdMRE is employed in 15 papers (31%). Therefore, these three measures were chosen to address the ReQ1.

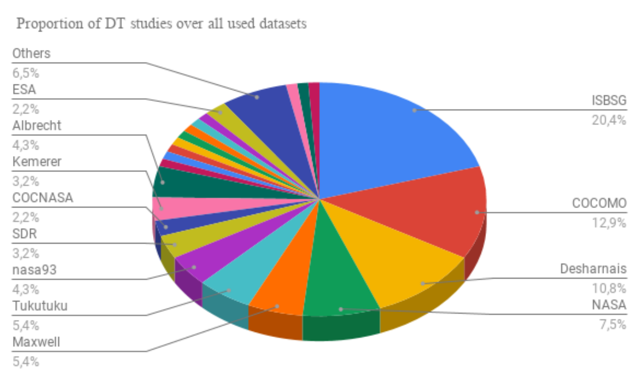

Fig. 2. The Proportion of DT Studies over all Datasets. (Others: for Databases without a well-known Name like Student Projects or Software House Projects).

TABLE II. DATASETS USED FOR DT EVALUATION.

Datasets	Total Number of studies	Proportion	Number of instances /number of studies
ISBSG	19	20,43	>1000/15, 789/1, 69/1, 500/1,501/1
COCOMO	12	12,9	63/9, 252/1
Desharnais	10	10,75	81/7, 77/3
NASA	7	7,53	60/3, 18/2, N/2
Maxwell	5	5,38	62
Tukutuku	5	5,38	53/3, 87/1, 150/1

N: The total number of database projects not specified

Though where it is not obvious to report directly the values of accuracy measures, we used the following logic: if there were various configuration models, we extracted the values of the best configuration, but if there were different database sampling, we calculate the means of the accuracy values. We take advantage of boxplots to have a clear interpretation of each accuracy criteria based on the values reported in articles.

Fig. 3 shows that the medians of accuracy values are as follows: median of MMRE is around 29%, the median of MdMRE 23%, and a median of Pred(25) is around 51%. It is known that contrary to Pred(25), lower values of MMRE and MdMRE show better estimation accuracy. From the data in Fig. 3 it is apparent that MMRE's distribution as well as that of MdMRE and Pred(25) present a positive dissymmetry because the medians are nearer to the inferior quartile.

What stands out in this figure by considering the distance between the lower and upper quartiles is the fewer variations of the values of MMRE. Therefore the box of MMRE is shorter than the boxes of MdMRE and Pred(25), elsewhere there is a possible explanation for this result: the values used for boxplots stem from various DT models that used different datasets specifications and several evaluation methods.

Typically, all databases apart from Tukutuku and COCOMO, have a mean of MMRE ranging between 17% and 68%, that of MdMRE between 11% and 44%, and that of Pred(25) between 36% and 89%. Therefore, it is awkward to report any conclusion because of the modest number of studies and experiments.

B. *Accuracy Comparison between DT Models and MaL/Non-MaL Techniques (ReQ2)*

This section set out to compare the preciseness of DT models with eleven MaL and Non-MaL methods: Regression (Reg), Radial Basis Function Neural Networks (RBFNN), COCOMO model (CCM), Use Case Point (UCP), Stepwise Anova (SA), Support-Vector Machines (SVM), Multilayer Perception (MLP), Case-Based Reasoning (CBR), Analogy Based Estimation (ABE), k-Nearest Neighbors (KNN), Association Rules (AR). To achieve this purpose, we had counted the amount of evaluations where DT models perform better (or less) than the eleven methods in terms of a particular estimation accuracy measure. Fig. 4 to 6, provide the results obtained from this comparison analysis (the "+" sign in front of MMRE/MdMRE/Pred signifies that DT methods perform better while the "-" sign signifies that DT methods perform less than the other models), we mention that the blue colors show the total examinations where DT methods perform better, while the red colors present the total examinations where DT methods perform less. Concerning Non-MaL methods, the majority of papers compare DT models with Reg models (87 examinations). From the data in Fig. 4 to 6, it is apparent that DT models perform better than Reg according to the MMRE measure. Similarly, regarding the MaL methods, the major part of DT papers makes a comparison with MLP (41 examinations), SVM (35 examinations), then RBFN and CBR (21 and 20 examinations respectively). According to the MMRE, MdMRE, and pred(25) values, we found that DT models perform better than MLP, RBFN, and CBR. Moreover, SVM outperforms DT methods in terms of the aforementioned three accuracy measures. However, for the remaining techniques, it is hard to report any inspection because of the few numbers of evaluations (less than 10 evaluations).

Additionally, all previously mentioned results are gathered from DT studies, so they might be subjective.

C. *Prediction Context of DT Methods (ReQ3)*

Given that, the investigated software effort estimation techniques provide various results, it is crucial to give closer attention to the favorable context of prediction more than looking for the perfect estimation model.

Mendes [22] has investigated numerous effort estimation techniques and asked a question: what technique to employ? The answer is "it depends". The main explanation is that the estimation depends on the context of prediction, which is related to database characteristics (dimension, outliers, attributes' types, missed data, and amount of collinearity) and different model designs.

Our review study intends to investigate these issues; therefore, we have retrieved and listed the advantages and limitations of DT techniques which were especially reported in the selected papers, see Table III. The main finding is that DT approaches have a greater sensitivity to the type and quality of historical datasets, which have a considerable effect on their estimation accuracy.

Some studies have examined the impact of dataset size on the estimation accuracy, it is found that DT techniques perform better with smaller datasets like in [23][9][24][25][26][27]. However opposed results were found, for instance [25] found that DT techniques can perform well when large datasets were employed. Nevertheless, it is challenging to confirm that DT techniques should be favorable in small datasets considering that satisfactory results were achieved in large datasets.

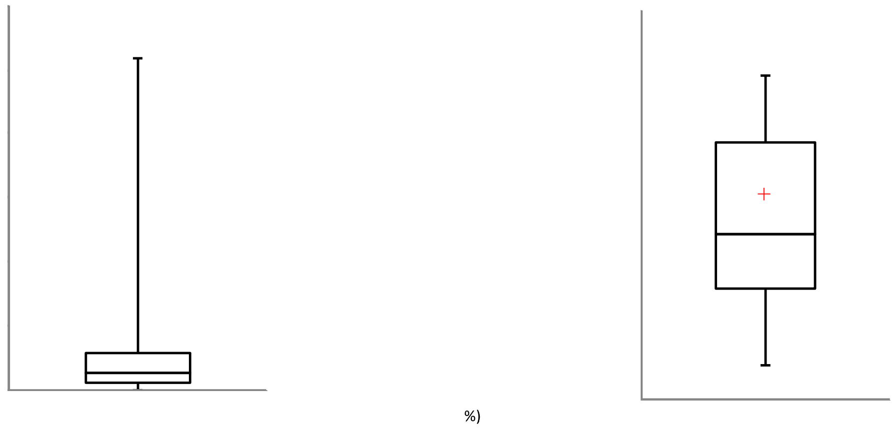

Fig. 3. Boxplots of MMRE(%), MdMRE(%), Pred(25%).

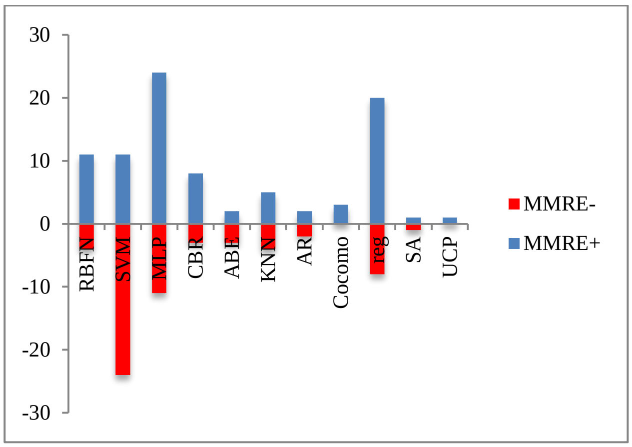

Fig. 4. Comparison of DT Methods with other Techniques in Terms of MMRE.

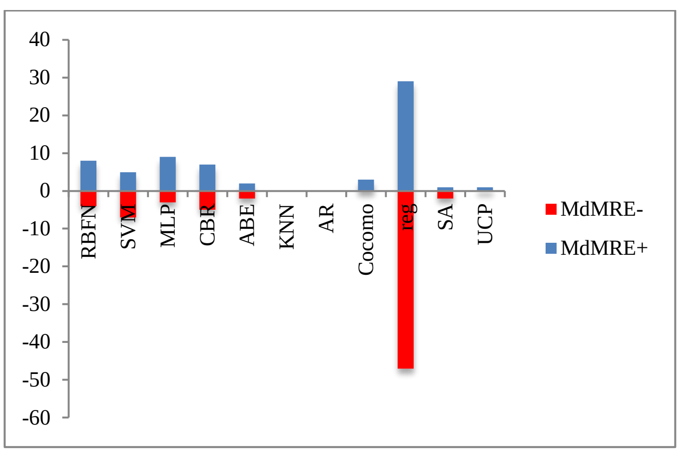

Fig. 5. Comparison of DT Methods with other Techniques in Terms of MdMRE.

Besides, DT techniques have a great challenge to extrapolate beyond the data on which it was trained, for example, these studies [8][28][27][29][30] confirm that DT techniques are typically unable to give accurate estimates for a project not similar to those available in the training set.

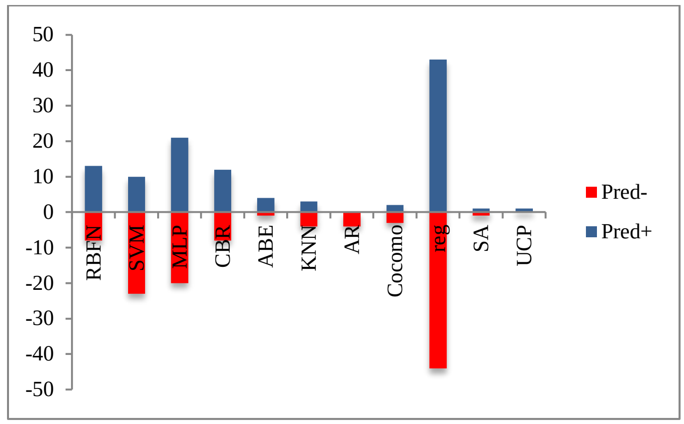

Fig. 6. Comparison of DT Methods with other Techniques in Terms of Pred(25).

Furthermore, classical DT methods cannot deal with imprecision and uncertainty [23][31][27]. As a result, numerous techniques have been suggested to handle imprecise data and therefore obtain more accurate estimates. In particular, [32][33][34] have suggested an improved technique which uses the concepts of fuzzy logic (FL). Their methods improve the performance of the traditional DT methods by incorporating the concept of FL theory.

One of the great advantages of using DT techniques is their resistance to outliers as reported in [14][25][35][27][10] and robustness to any multi-collinearity problems such as [36][37][38][27]. This is because DT methods perform an automatic feature selection as argued in these papers [14][39][36][40] which means that they just select the relevant features which have an important impact on the effort. Moreover, these studies [14][15][35] have shown that DT methods provide accurate effort estimation without performing a variable selection which strengthens the idea of resistance to multi-collinearity problems.

Other influencing factors must be taken into consideration along with dataset characteristics. They are all listed in Table III. For instance, The DT methods are suggested when it is difficult to describe the complex relationships that exist among project attributes and effort. This is because DT techniques guide the practitioners to know which effort factors have a potential effect on the prediction and how the model derives the results; this is why DT methods produce more interpretable and comprehensible results; also they can perform well at an early stage of project development with just early available attributes; which help practitioners at taking good decisions; but they require the use of historical dataset to generate an estimate.

TABLE III. ADVANTAGES AND LIMITATIONS OF A DT TECHNIQUE

Advantages	**Supporting studies**
A DT method can handle categorical variables.	[41], [34]
RTs could handle different scales of attributes.	[18], [34], [31]
DT is designed for exploratory data analysis.	[42]
Automatic handling of missing values.	[14], [27]
Resistance to outliers.	[14], [25], [35], [10], [27]
Automatic variable subset selection.	[14], [36], [39], [40]
DT methods are among the best even without feature selection.	[14], [15], [35]
Perform better with early available attributes' scheme.	[43], [41], [34]
DT methods are recommended for relevantly homogenous databases.	[42]
Can deal with imprecision and uncertainty.	[32], [33], [34]
The ability to learn from past finished projects and have predictive power.	[27], [30]
High comprehensibility and producing more interpretable results.	[8], [12], [22]–[24], [29], [31], [34], [35], [42], [44]–[46]
High applicability.	[23], [27], [29]
DTs are not used only for classification but also for regression issues.	[12], [22], [27], [29], [30], [37], [38], [46], [47]
Limitations	**Supporting studies**
It cannot extrapolate beyond the data on which it was trained.	[8], [27]–[30]
The sensitivity of DT approaches to the nature and quality of historical data.	[11], [12], [17], [18], [28], [30], [35], [40], [41], [46], [48], [49]
Not perform better on large datasets.	[9], [26], [27], [29]
Depends on the training set size.	[12], [46]
Classical DT methods Cannot deal with imprecision and uncertainty, medium uncertainty.	[23], [27], [31]
Low accuracy.	[8], [23], [30], [50]
Medium causality and medium sensitivity to parameters changes.	[23], [28], [39], [51]
Not provide any meta information to guide the project manager in the budgeting process.	[50]
Accuracy Not significantly sensitive to the company-specific data or multi-organizational data.	[9], [22], [26], [31], [31]
Some DT methods act as a black box.	[10]
Need completed and historic databases.	[22]

In sum, DT techniques have many advantages however; they suffer from some limitations, which can be bypassed by ensembles methods like in [52] or by the integration of other techniques.

There exist some studies such as [10][32][25][24][36][40][43][44][53][45][51] that recommend the use of hybrid models that incorporate other techniques along with DT methods to enhance the prediction accuracy.

Note that in the next section we will discuss concisely the impact of the combination of other techniques on the performance of DT models.

D. Effect of Combining a DT with Other Method (ReQ4)

The present subsection investigates the effect of combining a DT with another technique especially the effect of each technique on the estimation accuracy. Table IV gives the MMRE improvement along with MdMRE improvement and Pred(25) improvement for each method employed in association with DT approaches. We note that the accuracy improvement was made only for studies that report the accuracy of DT combination compared to the accuracy related to DT alone.

Table V provides more details about each associated method: the total number of articles dealing with each method, the number of articles comparing the accuracy, and the total examinations done in these papers. For instance, from the 8 papers, which combines Fuzzy Logic with DT (FL-DT) methods, just 2 papers made an estimation accuracy comparison with that of a DT method alone, and only 3 evaluations were made to assess the accuracy of the estimation. Meanwhile, for a certain number of methods, which are associated with DT models, the number of examinations was considerably greater than the total papers including those techniques. For example, grid search combined with generic backward input selection (GS+GBIS), there was only 1 study investigating the comparison of DT techniques with that of a GS+GBIS+DT technique, yet 9 evaluations were performed.

We mention that the number of combined methods may be (>=1) such as ABE line in Table V shows the accuracy values when combining (ABE) alone with DT techniques while (Boost+PCA+Poisson) line presents the values of accuracy when combining Bootstrapping, Principal Component Analysis (PCA) and Poisson Regression. In sum, note that the Bagging, Regression, Fixed Size Window Policy (FSWP), and (Boost+PCA+Poisson) were less incorporated with DT techniques (one examination by one paper).

Closer inspection of Table V, considering the number of evaluations and MMRE's median, FL is the best method, which strengthens the accuracy of DT techniques (92,56% improvement), followed by Boost+PCA+Poisson (88,33 %) and AR (78,22%). On the basis of the MdMRE's median, Boost+PCA combined with Poisson Regression has the most improvement (71.42%), followed by GS combined with GBIS (5.99%). According to the median of Pred(25), AR has the greatest effect (84.99% improvement), followed by FL (18.45%).

To prevent the bias coming from the evaluations made on the same study, we investigate the impact of combining other techniques with DT methods, by taking advantage of the totality of articles, instead of the totality of examinations. Table V shows that Reg, FL as well as ABE are the three methods frequently combined with DT techniques. Table IV indicates that according to Reg, FL lines as well as that of ABE, only FL technique has the greatest improvement based on the MMRE and Pred(25) accuracy measures.

To summarize the findings, we realize that not all presented methods in Table IV, contribute necessarily to the accuracy improvement of DT techniques mainly, FL, Bagging and AR are the only ones that improve both MMRE and Pred(25) criteria, which are supported by 2,1 and 1 studies respectively. We figured out that, Bagging contributes to a small improvement in accuracy when combined with DT techniques. Due to the fact that Bagging gives good results with good basic learners otherwise if the basic learner is bad, bagging may contribute to the degradation of the accuracy of estimates.

Moreover, AR appears to be a more promising technique than FL when combined with DT techniques since it improves significantly both accuracy measures MMRE and Pred(25).

Nevertheless, all these results require more evaluations in more search studies due to the restricted amount of papers that analyzed the effect of incorporating other techniques with DT.

E. DT Tools (ReQ5)

In this SLR we identify seven tools, which are listed in Table VI. Weka presents the mostly employed tool, then Matlab, SPSS AnswerTree version, and Fispro.

Weka is an application developed by researchers, it is open-source software based on Java. It contains a set of machine learning algorithms, in particular data preprocessing, clustering, classification, and AR extraction.

MATLAB is a numeric-computing environment that was developed by MathWorks but it was created by Cleve Moler in the 1970s. Also, there exist statistical tools built on MATLAB, which offer a set of unsupervised and supervised MAL algorithms including decision trees with boosting and bagging techniques.

TABLE IV. PERCENTAGE OF MMRE, MDMRE, AND PRED(25) IMPROVEMENT OF EACH ASSOCIATED METHOD WITH DT

Incorporated methods with DT	**Reference**	**Dataset**	**MMRE improvement (%)**	**MDMRE improvement (%)**	**Pred(25) improvement (%)**	**Incorporated methods with DT**	**Reference**	**Dataset**	**MMRE improvement (%)**	**MDMRE improvement (%)**	**Pred(25) improvement (%)**
FL	[32]	COCOMO'81	98	N	18,45	GS +GBIS	[48]	ISBSG	N	-1,25	0,44
	[32]	Tukutuku	92,41	N	2,01			Experience	N	4,2	5,22
	[1]	Tukutuku	92,56	N	40,15			ESA	N	2,55	3,4
Bagging	[45]	NASA	0,73	N	6,67			ISP05	N	9,11	2,54
ABE	[9]	House project	-16,21	-39,13	8,16			Euroclea	N	9,38	21,32
	[31]	Laturi	-89,16	-17,37	1,58			COCNASA	N	4,25	23,89
Reg	[9]	House project	2,7	-30,43	-5,44			coc81	N	14,52	14,41
PCA	[18]	NASA	-75,17	-107,72	-14,02			Desharnais	N	8,98	3,46
		USC	-144,06	-129,89	-15,36			Maxwell	N	5,99	-0,65
		SDR	-43,3	-73,16	-11,42	Boost+PCA +Poisson	[51]	Software House	88,33	71,42	N
FSWP	[40]	ISBSG	22,85	N	N	Voting Ensemb le	[49]	Coco81	-36,47	N	N
GA	[39]	Desharnais	3,09	N	9,98			nasa93	-43,01	N	N
		NASA	-3,37	N	0			cocomonasa_v1	-113,52	N	N
AR	[42]	ISBSG	76,18	N	90,15						
		STTF	80,27	N	79,84						

TABLE V. THE TOTALITY OF PAPERS COMPARING THE ACCURACY AND THE NUMBER OF EXAMINATIONS MADE FOR EACH ASSOCIATED METHOD WITH DT MODELS

	FL	**Bag**	**ABE**	**Reg**	**PCA**	**FSWP**	**GA**	**GS+GBIS**	**AR**	**Boost+PCA +Poisson**	**Voting Ensemble**	**Bees algorithm**
No. Of studies	**8**	2	**3**	**4**	2	1	1	1	1	1	2	1
Total papers comparing the accuracy	**2**	1	**2**	**1**	1	1	1	1	1	1	1	0
No. Evaluations	**3**	1	**2**	**1**	3	1	2	9	2	1	3	8

TABLE VI. DT TOOLS

Tool	Authors	Year	Studies using the tool	References
Weka	Hall et al.	2008	[45]	[54]
	Witten and Frank	2000	[49]	[55]
	Hall et al.	2009	[25][1], [35][1]	[56]
	N	N	[57][1], [58][7]	N
Matlab	N	N	[16], [24], [59], [34][2], [60][8]	N
SPSS Inc	N	N	[43][3], [34], [41][4], [12], [61][5], [47][6]	N
Fispro	Guillaume et al.	2002	[1],[32]	[62]
CART software	Dan and Colla	1995	[31], [26]	[63]
MART software (TreeNet)	Salford-Systems	1997	[14]	[64]

[1] – RepTree, [2]- v.7.5.0, [3]- v.15.0, [4]- v.17.0, [5] - AnswerTree v 2.1.1, [6] - AnswerTree v 3.1, [7] - v 3.8 REPTree, and M5P, [8] - v.7.1.

Over the whole selected papers, only a few studies have employed DT tools to obtain or generate software effort estimates. Moreover, the majority of the existing tools implement the traditional DT methods, which didn't integrate other techniques, for example, FL, GS (Grid Search) to enhance the estimates.

IV. SUMMARY AND IMPLICATIONS FOR SEARCH AND USE

Our suggestions concerning the use of DT models in SDEE concern are listed below:

The estimates' accuracy of DT methods: Due to the modest number of studies we were unable to draw any conclusion. Furthermore, the majority of studies use historic databases, so we suggest carrying out more works with the help of concrete and practical experience in the industrial sectors.

The accuracy of DT compared to that of MaL and Non-MaL methods: the DT techniques outperform some models including MaL and Non-MaL. Typically, RBFN, for which there were enough evaluations. Nevertheless, to report a definitive result is a challenging issue, because of the insufficient number of studies investigating accuracy comparison. It is therefore interesting for researchers to conduct more experiments to deal with this issue.

The suitable conditions for an accurate estimation of DT techniques: It should be noted, that it is difficult to make a conclusion concerning the use of DT techniques. Consequently, practitioners have to figure out which techniques had to be in combination with DT methods towards overcoming limitations relative to (missing values, categorical data, features selection, etc.) and accommodate DT to their context.

Effect of combination of other methods with DT methods: the accuracy of estimates of DT models was not usually enhanced. The results show that using bagging techniques doesn't improve greatly the accuracy of DT techniques in comparison with the AR and FL techniques. This indicates that MaL techniques are more desirable to be incorporated with DT methods rather than Non-MaL techniques.

DT tools: We have recognized in this review study, seven tools to estimate software effort using DT methods. Especially, WEKA and MATLAB are the tools most often used. Moreover, the majority of tools implement classical DT methods. It is therefore suggested for researchers to investigate the implementation of other techniques along with DT models that enhance significantly the estimates' performance like AR, FL, and Bagging and hence encouraging industrial utilization of DT amongst professionals.

V. LIMITATIONS OF THIS REVIEW

The three accuracy metrics used in this review are MMRE, MdMRE, and Pred(25).

However, these indicators don't take into account the quality of databases so implicitly they suppose that the estimation method may give estimates with a maximum precision of 100% for a particular database [65]. Additionally, the MMRE has been subject to criticism for being not balanced in several evaluation contexts in addition to its penalization character of overestimated values further than underestimated ones [66], [67]. Even though, in this review study, we are based on these three criteria, since they were widely employed in relevant articles.

In addition, it is challenging to define the circumstances of all estimates because they were obtained from the selected studies based on various DT techniques and using several experimental designs, which include design decisions (feature selection, project selection, split rule, stopping criteria, pruning, etc.) and validation methods (holdout, LOOCV, k-fold cross-validation, etc.).

Moreover, in this review, we consider only studies about DT techniques. For that reason, the mentioned performance of DT techniques would be overestimated, besides that, the advantages and limitations of each DT technique may be subjective. Therefore, the reader must also take into consideration the potential effect of the authors' concern and viewpoint on these results.

VI. CONCLUSION AND FUTURE WORK

This systematic review synthesizes the results of DT studies in conformity with software effort estimation. Moreover, the selected papers were examined according to the five perspectives: prediction accuracy, the performance of DT techniques in comparison with other methods, contexts of the estimates, and effect of the combination on DT's performance, and DT tools.

In sum, we identified 50 relevant papers, especially between the years 1985 and 2019. The important results found in this review study are as follows:

What is the overall performance of DT techniques? The overall picture suggests that no conclusive affirmation can be made since the mean accuracy values are around 52,5% for MMRE, 26,1% for MdMRE, and 56,1% for Pred(25).

What is the performance of DT techniques in comparison with other methods (MaL or Non-MaL)? In general, DT techniques outperform RBFN, MLP, and CBR techniques. Especially, they outperform also Regression models according to MMRE.

What are the suitable conditions for an accurate estimation of DT techniques? Many studies confirm that DT methods can describe the complex relationships that exist among project attributes and effort, and can produce more interpretable and comprehensible results. In addition to their resistance to outliers and robustness to any multi-collinearity problems. However, classical DT methods cannot deal with imprecision and uncertainty. Furthermore, several papers propose the use of hybrid models to overcome the existing DT limitations.

How the combination of other techniques with DT techniques does affect estimation accuracy? The techniques the most commonly used in combination with DT studies are fuzzy logic followed by regressions. However, not all combined techniques improve the accuracy estimation of DT techniques. Typically Association rules, fuzzy logic, and bagging are the techniques that improve the prediction accuracy of DT based on the MMRE and Pred(25) measures.

What are the most commonly used DT tools? WEKA, created by researchers at the University of Waikato is the most widely used tool to estimate effort using DT techniques.

In terms of future work, it would be interesting to perform a comparative study and repeat the experiment using unbiased evaluation criteria like the standard accuracy (SA), and the effect size rather than the biased MMRE.

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Genetic Algorithms for the Multiple Travelling Salesman Problem

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***Abstract*—We consider the multiple travelling salesman Problem (MTSP) that is one of the generalization of the travelling salesman problem (TSP). For solving this problem genetic algorithms (GAs) based on numerous crossover operators have been described in the literature. Choosing effective crossover operator can give effective GA. Generally, the crossover operators that are developed for the TSP are applied to the MTSP. We propose to develop simple and effective GAs using sequential constructive crossover (SCX), adaptive SCX, greedy SCX, reverse greedy SCX and comprehensive SCX for solving the MTSP. The effectiveness of the crossover operators is demonstrated by comparing among them and with another crossover operator on some instances from TSPLIB of various sizes with different number of salesmen. The experimental study shows the promising results by the crossover operators, especially CSCX, for the MTSP.**

Keywords—Multiple travelling salesman problem; NP-hard; genetic algorithm; sequential constructive crossover; adaptive; greedy; comprehensive

I. Introduction

The travelling salesman problem (TSP) is one well-known multidisciplinary problem in operations research and computer science, which aims to find a least length (cost) Hamiltonian cycle (circuit) in a network of cities. The problem can be defined as: Given a set of cities (nodes) and the distances among them. Starting from and finishing at single depot city, a salesman should visit all remaining cities exactly once such that the total travelling distance (cost) by the salesman is minimized. The TSP has been extensively studied by several researchers, and hence, several useful approaches have been suggested to solve it. However, certain problems require additional salesman, and thus, the multiple TSP (MTSP) is defined to generalize the usual TSP. In MTSP, all salesmen begin from and finish their journey at a single depot city. Each city, except the depot city, should be visited by only one salesman such that the total travelling distance (cost) by all salesmen is minimized [1].

The MTSP can be formally defined as: Let there are m salesmen placed at single depot in a n-city network, d_{ij}, (i, j=1, 2, ..., n) be the distance (cost) between the cities i and j, and 'city 1' be the 'depot' with the remaining cities, 2, 3, …, n be the intermediate cities. Each of the salesmen is to start from the depot and after touring his set of cities should return to the depot. The tours should have no common cities (except the depot). The purpose is to obtain the optimum tour plan, i.e., the order of cities for each salesman, so that the total distance(cost) of the tour is minimum. Clearly, if m = 1, the problem becomes usual TSP.

The distance matrix may represent cost, time, etc. Depending on the nature of the distance matrix, the TSPs are divided into two types - asymmetric and symmetric. If $d_{ij} = d_{ji}$, $\forall$i, j, then it is symmetric; otherwise, asymmetric. For n-city usual asymmetric TSP, there are (n-1)! possible number of routes. So, for 5-city problem instance, there are 24 probable routes, and there are possibly 120 routes for 6-city problem. However, for 10-city problem, there are 362,880 possible routes, which is huge. Thus, the computational work is directly proportional to the problem size. It is very hard to solve large sized instances, if not impossible. In addition, the MTSP needs first to determine the cities allocated to each salesman, then to order the optimal sequence of cities in each salesman's tour, so, it is more complicated than TSP. Since, the TSP is NP-hard, hence, MTSP is also NP-hard [2].

The MTSP is the most challenging optimization problem in operations research and computer science paving the ways to various scheduling and routing problems. The MTSP seems to be more appropriate than the TSP for practical applications and can be used to simulate many real-life applications. The problem can be applied on job scheduling where multiple parallel production lines are present [3]. Also, the vehicle routing problem can be modelled as the MTSP. The MTSP can be applied to another kind of TSP variant where a salesman visits n cities over a period spanning m weeks but returns to the home city during weekends [4]. The school bus scheduling problem is an application of the MTSP that obtains a bus loading pattern so that the total number of ways is minimized, the total distance travelled by all buses is kept at minimum, no bus is overloaded and the time required to traverse any route does not surpass a maximum allowed policy [5]. Crew scheduling is another application of the MTSP as reported in [6], where investigated the problem to schedule multiple photographers' groups to many schools. The applications also include print press scheduling [4], interview scheduling [7], mission planning [8], and the design of global navigation satellite surveying system networks [9].

The MTSP may be extended to many variations [1]. Number of depots may be single or multiple. Similarly, paths (tours) may be closed or open. A closed path begins and ends at a single depot, whereas an open path does not require returning to the original depot. This paper considers the MTSP that allows all salesmen to start from same depot and end their tours at the original depot.

The MTSP is very difficult, and no any polynomial-time algorithm is available for the problem. So, finding its optimal solution is very tough, if not impossible. Hence, researchers are looking for finding better heuristic solutions within an acceptable computational time, rather, finding accurate optimal solutions to the MTSP as well as other difficult optimization problems. Therefore, one must go for heuristic methods for solving the MTSP. Artificial neural network (ANN) [10], simulated annealing (SA) [11], genetic algorithm (GA) [12], particle swarm optimization (PSO) [13], ant colony optimization (ACO) [14], etc. are a few such approaches.

In the recent years, several GAs have been developed successfully for various difficult optimization problems, for example the quadratic assignment problem [15], the minimum spanning tree problem [16], and the TSP [17]. GAs first developed by John Holland in 1970s that are based on survival-of-the-fittest theory among different species created by arbitrary variations in the chromosomes' structure in the biology. The GA is very successful because it is simple, flexible and easy to encode. A GA always begins with an initial chromosome population that goes through mainly three basic operations, namely selection, crossover and mutation, in successive generations to produce better populations. In selection method, chromosomes are probabilistically copied to the next (iteration) generation. Crossover selects randomly two parent chromosomes and mates them to form new offspring chromosome(s). Mutation occasionally alters value (gene) at a chromosome position. The crossover along with selection is the most influential process in genetic search. Mutation diverges the search space and defends genetic material losses that may resulted from selection and crossover operators. Hence, probability of implementing mutation operator is fixed very low, while probability of implementing crossover is fixed very high [18]. Out of three genetic operators, crossover is the most vital operator, and hence, several crossovers have been used in GAs for the MTSP which are proposed for the TSP. Still, most crossover operators do not lead good GA. Selecting good crossover can lead to a successful GA. An experimental study reported on six crossover operators in [19] showed that sequential constructive crossover (SCX) is the best operator. Recently, several modified versions of SCX, namely adaptive SCX (ASCX) [17], greedy SCX (GSCX) [20], reverse greedy SCX (RGSCX) [21] and comprehensive SCX (CSCX) [21], and were suggested for the TSP which showed very good results for the TSP.

In this study, we first reduce the MTSP to the TSP by introducing some artificial depots and then develop different simple GAs using five crossover operators - SCX, ASCX, GSCX, RGSCX and CSCX for the MTSP. These crossover operators are first applied manually on a pair of parents to create offspring(s). The effectiveness of the crossover operators is demonstrated by comparing among them and with two-part chromosome crossover (TCX) [12], on some instances from TSPLIB of various sizes with different number of salesmen. The comparative study shows the effectiveness of the crossover operators, especially CSCX, for the MTSP.

This paper is prearranged as follows. Section II reviews the related research. Simple genetic algorithms for the MTSP are described in Section III. The comparative study is described in Section IV. Finally, conclusions and future investigations are reported in Section V.

II. Literature Review

The MTSP is one of the most tough NP-hard problems. The MTSP is not well-studied like the usual TSP. For a detailed survey of MTSP and its variations, its practical applications, solution approaches proposed so far, the reader is referred to [1]. As this study proposes genetic algorithms (GAs) for solving the problem, we give literature survey on GAs, especially crossover operators used in different GAs for the MTSP.

For solving the MTSP, the first GAs were proposed in [6]. For solving the MTSP that models hot rolling scheduling in Shanghai Baoshan Iron and Steel Complex, GAs are proposed in [22]. First, the problem is modeled as an MTSP, which is then converted into usual TSP and finally, applied a modified GA for finding solution of the problem.

In [23], grouping GAs have been proposed for the MTSP that obtain better solutions. Additionally, another objective function that minimizes the maximum (cost) distance travelled by any single salesman is considered.

In addition, several crossover operators that were developed for the TSP have been modified and applied to the MTSP. The ordered crossover (OX) [24], cycle crossover (CX) [25], partially mapped crossover (PMX) [26], edge recombination crossover (ERX) [27], alternating edges crossover (AEX) [27] and sequential constructive crossover (SCX) [28] etc. are the most widely used crossover operators for the TSP. However, these crossover operators cannot be applied directly in GAs with the two-part chromosome representation.

In [12], the two-part chromosome crossover (TCX) that minimizes the size of search space of the MTSP is developed to find solution for the problem. A comparative study has been reported against three distinct crossover methods, namely OX+A, PMX+A and CX+A, for bi-objective MTSP that considers total distance and longest tour as objective functions to be minimized. As reported, TCX finds better solutions than other three crossover operators.

In [29], a modified two-part chromosome crossover is proposed for the problem. As reported, the algorithm assigns various number of cities for different salesman and obtained good solutions.

In [4], a combined crossover operator, OX + A (OX combined with an asexual crossover [30]) was proposed for the two-part chromosome method. The OX and the asexual crossover were employed for the 1st and 2nd parts respectively of the chromosome. That is, each part of the chromosome is considered and processed separately using two different crossover methods. The theoretical properties of the method is investigated as well as computational efficiency of the method is reported. As reported, the newer technique minimizes the search space and obtains better solutions.

In [19], one chromosome representation is used and applied six crossover operators, OX, PMX, CX, ERX, AEX and SCX for solving the MTSP. As reported, the SCX is the best operator.

III. Simple Genetic Algorithms for the MTSP

A. Reduced Distance Matrix

The multiple-TSP can be transformed to the single-TSP by assuming single salesman. Similarly, the problem with n cities and m salesmen can be transformed into the usual TSP with n+m-1 cities by adding m-1 artificial depots (namely, n+1, …, n+m-1) [31]. Further, the VRP can be transformed to the MTSP by deleting capacity constraints [32]. However, we transform the MTSP to the TSP by adding m-1 artificial depots. An example of a solution of the MTSP with n=8, m=2 is shown in Fig. 1(a), whereas its transformation to the TSP is depicted in Fig. 1(b).

Further, the original distance matrix and the reduced distance matrix with one artificial depot ‘city 9’, for the same problem are shown in Tables I and II, respectively.

In general, GAs are very successful heuristic methods in obtaining solutions for the usual TSP and its different variations. GAs do not assure that the obtained solutions are optimal, but they usually obtain better and near optimal solutions very quickly.

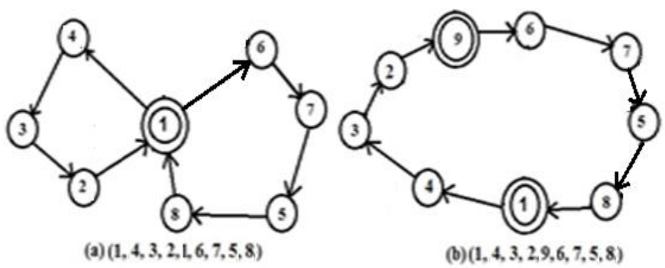

Fig. 1. Example of a Solution of the MTSP and its Transformation to the TSP with Artificial city 9.

TABLE I. The Distance Matrix

City	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	999	75	99	9	35	63	8	11
2	51	999	86	46	88	29	20	15
3	100	5	999	16	28	35	28	2
4	20	45	11	999	59	53	49	8
5	86	63	33	65	999	76	72	5
6	36	53	89	31	21	999	52	6
7	58	31	43	67	52	60	999	9
8	15	95	66	14	54	8	87	999

TABLE II. The Reduced Distance Matrix

City	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	999	75	99	9	35	63	8	11	999
2	51	999	86	46	88	29	20	15	51
3	100	5	999	16	28	35	28	2	100
4	20	45	11	999	59	53	49	8	20
5	86	63	33	65	999	76	72	5	86
6	36	53	89	31	21	999	52	6	36
7	58	31	43	67	52	60	999	9	58
8	15	95	66	14	54	8	87	999	15
9	999	75	99	9	35	63	8	11	999

B. Chromosome Representation

To use GA for any optimization problem, one should find a method to represent solutions by legal chromosomes so that crossover produces legal chromosomes. There are three representation methods used for chromosome for the MTSP. They are one chromosome method [22], two chromosomes method [33], and two-part chromosome method [34-35]. Brown et al. [36] proposed another chromosome representation method which is inspired from the chromosome representation described in [34]. This representation consists of two sections - main section and group section. The main section of the chromosome consists of n real-valued genes and group section consist of m integer-valued genes. The integer part of the real-valued gene i in the main section indicates the salesman assigned to city i, whereas fractional part determines the order in which city i is visited. Group section simply shows various groups exist in the solution in the way they appear in the main section. This is a deviation from the representation described in [34], where groups can appear in any order in the group section. Singh and Baghel [23] proposed another chromosome representation method which represents chromosome as a set of m tours, i.e., there is no sequence among the tours. As reported, GA using this representation method is found to be superior.

We are going to choose one-chromosome with artificial depots. An example of our chromosome for $n = 8$ with $m = 2$ is shown in Fig. 2.

1	4	3	2	9	6	7	5	8

Fig. 2. An Example of our One Chromosome for 8 Cities with 2 Salesmen.

In this chromosome, (1, 4, 3, 2, 9, 6, 7, 5, 8), there are (8+2-1=) 9 genes including artificial depot city 9. This chromosome represents the tour $\{1\rightarrow4\rightarrow3\rightarrow 2\rightarrow9\rightarrow6\rightarrow 7\rightarrow5\rightarrow8\rightarrow1\}$. That means, the 1st salesman visited cities 1, 4, 3 and 2 sequentially, and the 2nd salesman visited cities 6, 7, 5, and 8 sequentially. The objective function is defined as total distances travelled by the salesmen, which is (9+11+5+51+63+52+52+5+15=) 263 for this tour.

A set of random of chromosomes is generated initially (initial population) to start the genetic search process, which are then evaluated and gone through a selection procedure for creating mating pool. In GAs, the crossover operator executes very important role. Generally, the crossover operators developed for the usual TSP, are considered for its variations also. Numerous crossover operators are developed for the usual TSP and among them SCX, adaptive SCX, greedy SCX, reverse greedy SCX and comprehensive SCX are considered and discussed here.

C. Sequential Constructive Crossover Operator

In [28], the sequential constructive crossover (SCX) operator is developed for the TSP, and then is updated in [37]. It creates only one offspring at a time that uses better edges available in the parents. Moreover, it uses some better edges which are not available in either of the parents. The main characteristic of SCX is to sequentially examine the parents to consider first legitimate (unvisited) cities seen after the current city. If no legitimate city is seen in a parent, it examines from the beginning of (wrapping around) the parent. It then compares their distances from the present city to choose the next city of the child. It is effectively applied to various combinatorial optimization problems ([15], [38]-[41]). We apply this crossover operator for the MTSP. It is seen that the SCX may lead to infeasible chromosomes (tours). So, we applied swap algorithm on the infeasible chromosomes to make them feasible. The swap algorithm randomly selects two cities and exchanges them. We now illustrate the SCX using following parent chromosomes with 9-city and 2-salesman, P_1: (1, 5, 7, 2, 9, 4, 3, 6, 8) and P_2: (1, 4, 6, 3, 7, 9, 2, 5, 8) with total travel distances 265 and 420 respectively using the reduced distance matrix given in Table II. This SCX operator results single offspring from two parents.

City 1 is the 1st gene, and after this, 5 and 4 are the legitimate cities in P_1 and P_2 respectively with d_{15}=35 and d_{14}=9. As $d_{14}<d_{15}$, city 4 is accepted. So, the incomplete chromosome (offspring) becomes (1, 4).

After city 4, 3 and 6 are the legitimate cities in P_1 and P_2 respectively with d_{43}=11 and d_{46}=53. Since $d_{43}<d_{46}$, we accept city 3. So, the incomplete chromosome becomes (1, 4, 3).

After city 3, 6 and 7 are the legitimate cities in P_1 and P_2 respectively with d_{36}=35 and d_{37}=28. Since $d_{37}<d_{36}$, we accept city 7. So, the incomplete chromosome becomes (1, 4, 3, 7).

The legitimate cities after city 7 in P_1 & P_2 are 2 & 9 respectively with d_{72}=31 and d_{79}=58. Since $d_{72}<d_{79}$, we accept city 2. So, the incomplete chromosome becomes (1, 4, 3, 7, 2).

The legitimate cities after city 2 in P_1 & P_2 are 9 & 5 respectively with d_{29}=51 and d_{25}=88. Since $d_{29}<d_{25}$, we accept city 9. So, the incomplete chromosome becomes (1, 4, 3, 7, 2, 9).

The legitimate cities after city 9 in P_1 & P_2 are 6 & 5, respectively with d_{96}=63 and d_{95}=35. Since $d_{95}<d_{96}$, we accept city 5. So, the incomplete chromosome becomes (1, 4, 3, 7, 2, 9, 5). By following this way, one can create the complete offspring as: (1, 4, 3, 7, 2, 9, 5, 8, 6) with distance 214, which is better than both parents.

D. Adaptive Sequential Constructive Crossover Operator

In [17], a modified version of the SCX, named adaptive SCX (ASCX), is developed for the TSP which creates only one offspring adaptively, either in forward or backward or mixed direction depending on next city's distance. Eight neighbour (four from each parent) cities of any current city is considered, of which best city in either direction is selected for the offspring. Since number of genes in a chromosome is n, 'city 1' is fixed as 1st and (n+1)th (not shown in the chromosomes) genes. We apply this crossover operator also. For any infeasible chromosomes (tours), swap algorithm is applied to make it feasible. This ASCX is explained using the same example.

For our example, 'city 1' is fixed in 1st and 10th (not shown in the chromosomes) places. In P_1, after 'city 1' (1st gene), legitimate cities in forward and backward (after wrapping around) directions are 5 and 8, respectively; and in P_2 they are 4 and 8, respectively, with their distances 35, 11, 9 and 11 respectively. Among them, the city 4 with distance 9 is the cheapest. From the end, in P_1, before 'city 1' (10th gene), legitimate cities in backward and forward (after wrapping around) directions are 8 and 5, respectively; and in P_2 they are 8 and (after wrapping around) 4, respectively, with their distances 15, 86, 15 and 20, respectively. Among them, the city 8 with distance 15 is the cheapest. Then city 4 is added as the 2nd gene in the offspring, as it is cheaper between the cheapest cities. So, the offspring becomes (1, 4, *, *, *, *, *, *, *).

In P_1, after 'city 4' (2nd gene), legitimate cities in forward and backward directions are 3 and 9, respectively; and in P_2 they are (after wrapping around) 6 and 8, respectively, with their distances 11, 20, 53 and 8, respectively. Among them, the city 8 with distance 8 is the cheapest. From the end, in P_1, before 'city 1' (10th gene), legitimate cities in backward and forward (after wrapping around) directions are 8 and 5 respectively; and in P_2 they are 8 and (after wrapping around) 6 respectively, with their distances 15, 86, 15 and 36 respectively. Among them, the city 8 with distance 15 is the cheapest. Then city 8 is added as the 3rd gene in the offspring, as it is cheaper between the cheapest cities. So, the offspring becomes (1, 4, 8, *, *, *, *, *, *).

In P_1, after 'city 8' (3rd gene), legitimate cities in forward (after wrapping around) and backward directions are 5 and 6 respectively; and in P_2 they are (after wrapping around) 6 and 5, respectively, with their distances 54, 8, 8 and 54, respectively. Among them, the city 6 with distance 8 is the cheapest. From the end, in P_1, before 'city 1' (10th gene), legitimate cities in backward and forward (after wrapping around) directions are 6 and 5 respectively; and in P_2 they are 5 and (after wrapping around) 6, respectively, with their distances 36, 86, 86 and 36 respectively. Among them, the city 6 with distance 36 is the cheapest. Then city 6 is added as the 4th gene in the offspring, as it is cheaper between the cheapest cities. So, the offspring becomes (1, 4, 8, 6, *, *, *, *, *).

In P_1, after 'city 6' (4th gene), legitimate cities in forward (after wrapping around) and backward directions are 5 and 3 respectively; and in P_2 they are 3 and (after wrapping around) 5, respectively, with their distances 21, 89, 89 and 21 respectively. Among them, the city 5 with distance 21 is the cheapest. From the end, in P_1, before 'city 1' (10th gene), legitimate cities in backward and forward (after wrapping around) directions are 3 and 5, respectively; and in P_2 they are 5 and (after wrapping around) 3, respectively, with their distances 100, 86, 86 and 100, respectively. Among them, the city 5 with distance 86 is the cheapest. Then city 5 is added as the 5th gene in the offspring, as it is cheaper between the cheapest cities. So, the offspring becomes (1, 4, 8, 6, *, *, *, *, *). By following this way, one can create the complete offspring as: (1, 4, 8, 6, 5, 3, 2, 9, 7) having distance 201, which is better than both parents.

E. Greedy Sequential Constructive Crossover Operator

In [20], a greedy SCX (GSCX) is proposed for the TSP that modified the SCX as follows. While searching the 'legitimate city' seen after the current city, if 'legitimate city' is not found in a parent, then select the cheapest 'legitimate city' from the set of remaining legitimate cities and add it to the current incomplete offspring chromosome. We apply this crossover operator also. For any infeasible chromosomes (tours), swap algorithm is applied to make it feasible. This GSCX is explained using the same example.

As 'city 1' is the first gene, after this city, the legitimate citys in P_1 is 5 and in P_2 is 4 having d_{15}=35 and d_{14}=9. As d_{14}<d_{15}, the city 4 is added as the second gene in the current offspring that leads the incomplete offspring to (1, 4).

City 1 is the 1st gene, and after this, 5 and 4 are the legitimate cities in P_1 and P_2 respectively with d_{15}=35 and d_{14}=9. As d_{14}<d_{15}, city 4 is accepted. So, the incomplete chromosome (offspring) becomes (1, 4).

After city 4, 3 and 6 are the legitimate cities in P_1 and P_2 respectively with d_{43}=11 and d_{46}=53. Since d_{43}<d_{46}, we accept city 3. So, the incomplete chromosome becomes (1, 4, 3).

After city 3, 6 and 7 are the legitimate cities in P_1 and P_2 respectively with d_{36}=35 and d_{37}=28. Since d_{37}<d_{36}, we accept city 7. So, the incomplete chromosome becomes (1, 4, 3, 7).

The legitimate cities after city 7 in P_1 & P_2 are 2 & 9 respectively with d_{72}=31 and d_{79}=58. Since d_{72}<d_{79}, we accept city 2. So, the incomplete chromosome becomes (1, 4, 3, 7, 2).

The legitimate cities after city 2 in P_1 & P_2 are 9 & 5 respectively with d_{29}=51 and d_{25}=88. Since d_{29}<d_{25}, we accept city 9. So, the incomplete chromosome becomes (1, 4, 3, 7, 2, 9).

The legitimate cities after city 9 in P_1 & P_2 are 6 & 5 respectively with d_{96}=63 and d_{95}=35. Since d_{95}<d_{96}, we accept city 5. So, the incomplete chromosome becomes (1, 4, 3, 7, 2, 9, 5). By following this way, one can create the complete offspring as: (1, 4, 3, 7, 2, 9, 5, 8, 6) with distance 214, which is better than both parents.

F. Reverse Greedy Sequential Constructive Crossover Operator

In [21], the GSCX is modified for the TSP by applying it in reverse way and termed as reverse GSCX (RGSCX). It constructs an offspring in reverse way, which is, from the last city (gene) back to the first city (gene). We apply this crossover operator also. For any infeasible chromosomes (tours), swap algorithm is applied to make it feasible. This RGSCX is explained using the same example.

The 'city 1' is the 10th gene. In both P_1 and P_2, 9th genes are city 8, hence, it is added as the 9th gene to the offspring as (8).

Before city 8, in P_1 and P_2, the legitimate cities are 6 and 5 respectively with d_{68}=6 and d_{58}=5. As d_{58}<d_{68}, the city 5 is added at the 8th place in the offspring as (5, 8).

Before city 5, legitimate city is not present in P_1. So, the cheapest legitimate city 6, among the remaining cities, is added at the 7th place in the offspring as (6, 5, 8).

Before city 6, in P_1 and P_2, the legitimate cities are 3 and 4 respectively with d_{36}=35 and d_{46}=53. As d_{36}<d_{46}, the city 3 is added at the 6th place in the offspring as (3, 6, 5, 8).

Before 'city 3', in both P_1 and P_2, legitimate cities are city 4, hence, it is added at the 5th place in the offspring as (4, 3, 6, 5, 8).

Before city 4, legitimate city is not present in P_2. So, the cheapest legitimate city 9, among the remaining cities, is added at the 4th place in the offspring as (9, 4, 3, 6, 5, 8). By following this way, one can create the complete offspring as: (1, 7, 2, 9, 4, 3, 6, 5, 8) having distance 186, which is better than both parents.

G. Comprehesive Sequential Constructive Crossover Operator

The comprehensive SCX (CSCX) is proposed in [21] that combines GSCX and RGSCX to create two offspring. We apply this crossover operator also. By using same parents' example, the offspring (1, 4, 3, 7, 2, 9, 5, 8, 6) and (: (1, 7, 2, 9, 4, 3, 6, 5, 8) are created, with distances 214 and 186 respectively which are better both parents.

H. Swap Mutation Operator

The mutation operator generally selects a gene (position) randomly in a chromosome and modifies its corresponding allele (city). Since always weaker chromosomes in consecutive generations are rejected in previous operators in GA search, so, some better alleles could be lost permanently. Hence the mutation is used for recovering them. Generally, one can assume that mutation may help the other operators to overcome local optima and obtain better solution. For our simple GAs, the swap mutation operator [18] which randomly chooses two cities, except artificial depots, and swaps them.

I. Structure of our Simple GAs

Our GA is simple that uses traditional genetic procedures and operators without incorporating another heuristic method. Starting with randomly created population, stochastic remainder for selection, only one selected crossover and swap mutation are used in our simple GAs (SGAs) as follows.

```
SGA ()
{ Initialize population of size Ps randomly;
  Evaluate the population;
  Generation = 0;
  While stopping criterion is not fulfilled
  { Generation = Generation + 1;
    Choose fitter chromosomes by stochastic remainder selection;
    Choose a crossover and perform crossover with probability Pc;
    Swap randomly chosen genes with probability Pm;
    Evaluate the population;
  }
}
```

IV. Computational Experiments

Our proposed SGAs using five crossover operators - SCX, ASCX, GSCX, RGSCX and CSCX, are encoded in Visual C++. In order to demonstrate the efficiency of the algorithm, computational experience is conducted on three benchmark TSPLIB instances [42] with different number of salesmen and run on a Laptop with i3-3217U CPU@1.80 GHz and 4 GB RAM under MS Windows 7. The instances MTSP-51, MTSP-100, and MTSP-150 used in [12] are considered for comparing our five crossovers with state-of-the-art crossover TCX reported in [12]. The success of GAs depends on proper selection of the GA parameters-termination criterion, crossover probability, population size, and mutation probability. But there is no intelligent way to select these parameters. One way to select them is by trial and error method. We run our SGAs for different setting of parameters, and selected parameters are listed in Table III.

We first compare our crossovers in SGAs with TCX [20] for three Euclidean symmetric instances – MTSP-51 with m=3, 5, 10; MTSP-100 with m=3, 5, 10, 20; and MTSP-150 with m=3, 5, 10, 20, 30. There is no restriction on the maximum of cities that a salesman can visit, however, each salesman should visit at least one city. The Table IV reports best solution (BestSol), average solution (AvgSol) and standard deviation (S.D) of the solution. For every instance, the best result over six crossovers is marked by boldface.

TABLE III. Parameter for our Proposed SGAs

Parameters	Values
Population size	50
Crossover probability	100%
Mutation probability	10%
Termination criterion	2000 generations
No. of runs for each instance	30 times

TABLE IV. Results by the Crossover Operators for Symmetric TSPLIB Instances

Instance	m	Results	TCX	SCX	ASCX	GSCX	RGSCX	CSCX
MTSP-51	**3**	Best Sol	466	456	**454**	460	457	458
		Avg. Sol	510	480	**464**	471	473	470
		S.D.	24	9	5	6	6	4
	5	Best Sol	499	488	486	481	**477**	490
		Avg. Sol	536	496	494	**490**	495	501
		S.D.	26	3	3	4	4	5
	10	Best Sol	602	621	596	**568**	**568**	580
		Avg. Sol	636	631	618	594	**587**	611
		S.D.	17	6	6	12	9	9
MTSP-100	**3**	Best Sol	28943	25107	24443	24875	24063	**22826**
		Avg. Sol	32708	25746	24750	25606	25507	**23731**
		S.D.	2267	477	181	470	512	405
	5	Best Sol	30941	26317	25900	25104	26037	**24196**
		Avg. Sol	34179	27250	26574	26798	27025	**25338**
		S.D.	2006	545	329	619	579	437
	10	Best Sol	32802	31149	30425	29721	**29181**	**29181**
		Avg. Sol	36921	32422	31246	31230	31227	**30256**
		S.D.	1964	565	439	702	874	541
	20	Best Sol	44112	44543	42407	42266	42665	**41465**
		Avg. Sol	46976	45989	44936	44032	44619	**43004**
		S.D.	1773	814	1268	898	1196	730
MTSP-150	**3**	Best Sol	51126	33404	30360	30824	30661	**29390**
		Avg. Sol	55851	34974	31627	32180	32260	**30921**
		S.D.	2588	930	676	531	537	553
	5	Best Sol	51627	34531	31151	32281	32459	**30308**
		Avg. Sol	61596	35844	32660	33403	33397	**31820**
		S.D.	4759	680	607	531	458	592
	10	Best Sol	54473	36514	**35510**	36576	35733	35802
		Avg. Sol	61360	38344	**36933**	37702	37150	37173
		S.D.	3888	643	592	638	835	643
	20	Best Sol	62456	48354	45564	46603	47096	**44697**
		Avg. Sol	69701	49450	47257	48560	49162	**46609**
		S.D.	4340	616	711	883	1064	796
	30	Best Sol	76481	63624	62565	61579	60758	**58757**
		Avg. Sol	84008	65812	65417	63760	64926	**61360**
		S.D.	5285	1389	2335	1198	1888	911

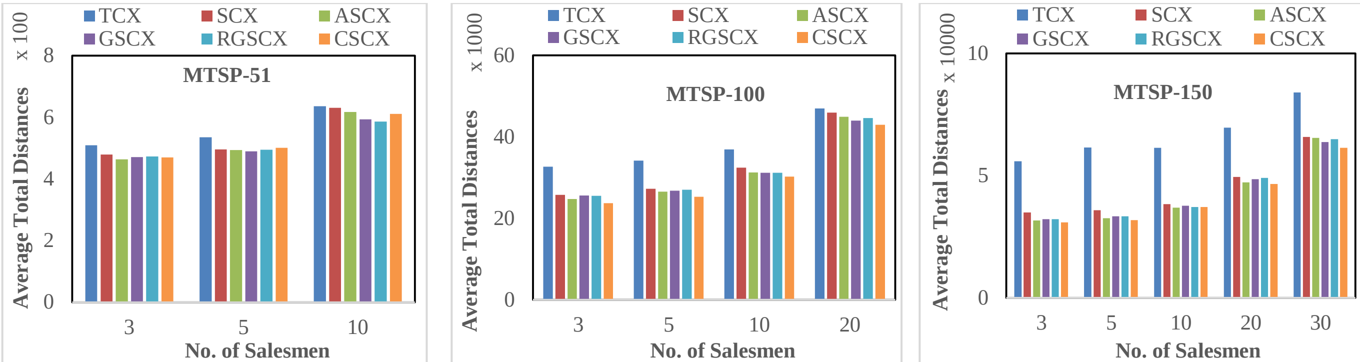

Fig. 3. Average Solution for the MTSP-51, MTSP-100 and MTSP-150 for different Crossover Operators.

The operators TCX and SCX could not find either lowest best or average solution for any instance. The operator GSCX finds lowest best solution for MTSP-51 with m=10 and lowest average solution for MTSP-51 with m=5; ASCX obtains lowest best and average solutions for MTSP-51 with m=3 and MTSP-150 with m=10; RGSCX obtains lowest best solutions for MTSP-51 with m=5,10, and MTSP-100 with m=10, and lowest average solution for MTSP-51 with m=10; and CSCX finds lowest best and average solutions for MTSP-100 with m=3, 5, 10, 20, and MTSP-150 with m=3, 5, 20, 30. From Table IV, it can be seen that CSCX gives more efficient results for most instances, and hence found to be very effective crossover operator. The results are showed in Fig. 3 that further demonstrates the effectiveness of the CSCX. From this study, it is concluded that CSCX is placed in 1st rank, ASCX in 2nd rank and TCX in the worst rank. To confirm these findings, statistical analysis is also carried out and found same results.

V. Conclusion and Future Works

In this study we considered the multiple travelling salesman problem (MTSP) which is a generalization of the travelling salesman problem (TSP). To solve this problem numerous genetic algorithms (GAs) based on numerous crossover operator have been reported in the literature. Choosing effective crossover operator can lead to effective GA. Generally, crossover operators that are proposed for the TSP are used for the MTSP also. We developed five simple GAs using sequential constructive crossover (SCX), adaptive SCX (ASCX), greedy SCX (GSCX), reverse greedy SCX (RGSCX) and comprehensive SCX (CSCX) for solving the MTSP. First, these crossover operators are applied manually on parent chromosomes to create offspring(s) and then encoded in Visual C++. The effectiveness of the crossover operators is demonstrated by comparing among them and with another crossover operator (TCX) on some instances from TSPLIB of various sizes with different number of salesmen. The experimental results show promising results by the crossover operator CSCX for the MTSP.

In this present study, we aimed to develop simple GAs using five crossovers and then compare among them and with a state-of-art crossover operator. We did not aim to develop improved and high quality GA. Though CSCX finds very good solutions, yet it gets trapped in local minimums in the early generations, and for small-sized instances, it does not show promising results. Therefore, effective local search and immigration methods could be combined to hybridize the simple GA for finding better solutions to more instances that is under our study.

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Stage Identification and Classification of Lung Cancer using Deep Convolutional Neural Network

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***Abstract*—The performance of lung segmentation is highly dependent on disease prediction task. Challenges for prediction and segmentation raise the need of using multiple learning techniques. Current models initially perform image segmentation in all CT scan images and then classify it as malicious or benign. This consumes more time since it segments both normal and abnormal CT's. So, due to improper segmentation of images the region of interest will be inaccurate and results in false classification of images. Therefore, by initially checking the CT which has malignancy and then segmenting those lesions will provide more accuracy in segmentation of cancerous nodules thereby helps to identify the stage of cancer the patient is suffering from. The aim is to improve the current cancer detection techniques using DCNN by filtering out malignant CT scan from the medical dataset and segmenting those images for stage identification. Segmentation is done using UNET++ architecture and stage identification is done by considering the "size" (T) parameter from the globally recognized standard named "TNM staging" for classifying the spread of each malignant nodule as T1-T4. 99.83 % accuracy is achieved in lung cancer classification using VGG-16 which yields better results for both segmentation and stage identification too.**

Keywords*—Computer Aided Diagnosis (CAD); Deep Convolutional Neural Network (DCNN); pulmonary nodule; segmentation; benign; malignant; staging

I. Introduction

Computed Tomography (CT) scans are well set up for detecting lung nodules [26]. A tumor is a mass of tissue that's formed by an accumulation of abnormal cells. Tumors can be benign or malignant. When we speak of "cancer" we refer to those tumors that are considered malignant. Malignant tumors that are fast growing and tend to spread to other parts of the body called metastasis, allowing tumor cells to enter the bloodstream or lymph system and other parts of the body, while benign tumors do not spread to other parts of the body. Lung cancer tends to spread at an early stage so, it is one of the most challenging tasks to diagnose the disease as early as possible. Especially the adrenal glands, liver, brain, and bone are some most prevalent places for lung cancer metastasis. But by using a single detector CT scan, the small lesions in the lung still remain difficult to spot. When pursuit early detection of lung cancer this poses itself as a dare. Since early detection is the key for a successful detection and healing, the incompetence to manually diagnose the small lesions further obstruct the possibility of early diagnosis.300 cross-sectional 2D images are currently produced by each CT scanners. And under particular time constraint each of which must be individually evaluated. Apart from the particular diagnostic benefits furnished by the CT imaging, the probability of error rate of cancer detection will be high due to the manual interpretation that is required for analyzing 200-300 slices per exam. Thus, detection of lung cancer becomes highly labor-intensive since tumor vary in position, size, shape depending on the patient. This increases false positives in detecting cancer either by detecting cancer in a patient who is cancer free, or by failing to detect the tumor. Current studies of a radiologist who have examined more than 20 CT examinations per day give evidence that 7% - 15% is the rate of mispredictions occurring in CT based malignancy diagnosis systems. So, in order to tackle this issue CAD systems were nowadays used for medical diagnosis due to accessibility of surplus data pertaining to the CT scan patients. Several approaches like image processing, data mining, and machine learning [25] are proposed for addressing the disease prediction task. On that account, to verify that oddity and divergence properly handled models came into existence and for classification of complex images deep learning has come into existence. The performance of lung segmentation is highly dependent on disease prediction task. Challenges for prediction and segmentation raise the need of using multiple learning techniques.

Current models initially perform image segmentation in all CT scan images and then classify it as malicious or benign. This consumes more time since it segments both normal and abnormal CT's. So, due to improper segmentation of images the region of interest will be inaccurate and results in false classification of images. Therefore, by first checking the CT that has malignancy and then segmenting those lesions, it will provide more precision in the segmentation of cancerous nodules, thereby helping to identify the stage of cancer that the patient is suffering from. Cancer detection technique is improved using DCNN by filtering out malignant CT scan from whole medical dataset and segmenting those images using UNET++ for stage identification and stage identification is done by considering the "size" i.e. T parameter from the standard named "TNM staging".

The paper is organized as Section II, discusses major detection techniques done in lung cancer. Section III explains the proposed approach comprising of three phases viz. Lung Cancer Detection, Malignant Nodule Segmentation, Lung Cancer Stage Identification respectively. Section IV discusses the details of the implementation and dataset used. Section V deals with the experimental findings and ultimately Section VI deals with the conclusion.

II. Literature Survey

In the literature number of researches on image processing techniques exist to detect cancer detection. But there is no improvement in the hit ratio of early stage cancer detection. With the advancement in machine learning techniques, many researchers are trying to diagnose cancer early as possible. Neural network plays a major part in recognizing cancerous area(malignant), which provides an effective tool for cancer detection. The cancer treatment will only be effective if the tumor cells are precisely separated from the normal cells. For each medical recognition task, differently modelled CNN needs to be employed. Compared to conventional methods, deep convolutional neural network gives much more processing magnitude and it gives more explicit results.

A Discriminative Feature Network (DFN), was introduced in [1] which contains Smooth Network and Border Network. A Smooth Network was introduced, which contains both Channel Attention Block and global average pooling to point out the discriminative features. A Border Network was also introduced along with it to distinguish boundaries of bilateral features with deep semantic boundary supervision to handle the intra-class in-consistency problem. Smaller strides or patching with a lot of overlapping in done in both which results in computationally intensive results in redundant information. Secondly, in the field of biomedical image, analysis is constrained by the lack of huge annotated samples. Small patches and large patches result in loss of contextual information and tamper with the localization results respectively. Loss of context information appears due to non-overlapping patches. An architecture called U-Net convolution is implemented in [2] exclusively for segmenting the biomedical images. Primarily U-Net employs data augmentation technique which does not create limitation in the number of data. Different color contrast remains to be a challenging task due to the staining procedure, cell structure in various histopathological images. So, in [3] not only extract the semantic information of the former layer, this do pay much attention to the shallower layers' semantic information by introducing RIC-UNET for image segmentation and classification. Residual block extract more characteristic features for segmentation. Inception module is for its computational efficiency while incorporating multiscale features with kernels of different sizes. Channel attention mechanism can focus the parameter training on the region of interest and alleviate the over fitting problem. Whole mammogram image was trained to an End to end deep multi-instance networks for mass classification. It was not on the basis of region of interest (ROI). So, in [4] introduced CAD systems for mammogram samples. It classifies both benign and malignant mass lesions. Using a threshold and region-based techniques for segmentation, DCNN is connected to SVM to obtain better classification results. Particle Swarm Optimization (PSO) algorithm based 2-D CNN is discussed in [5] using LIDC dataset to remove the network hyper-parameter's manual searching. 2-D U-Net is employed along with an ensemble of XGBoost and RF for nodule feature classification in [6]. Employing 3-DCNN, pulmonary nodule detection can be done through reinforcement learning technique. In [7] proposed a 3-dimensional U-Net, Dense Net and Region Proposal Network for pulmonary nodule detection in CT lung images. Here, candidate selection is done through U-net based RPN and false classification is reduced by using Dense Net. In [8] 3-D faster RCNN model similar to U-Net is used for creating nodule and DCNN is employed for finding out nodules.3-D based group convolutional neural network (G-CNN) [9] is proposed for medical diagnosis having almost similar performance rate as that of normal CNN but demands high utility of data than normal CNN. Various-sized input data for classification of lung nodule as benign and malicious are introduced by incorporating multiple 3-D CNN [10]. Prediction can also render both 2-D and 3-D approaches. In 2-D CNN [11], both local and global features are taken and classified. The hybrid version of Alex Net and LeNet determines the malignancy in the tumor by just adopting the layers from LeNet and network parameters from Alex Net thereafter it got its name as Agile CNN[12] and have an accuracy of 82.2%.For finding the degree of malignancy in lung images, 3-D CNN model uses different approaches mainly by adopting previous multi-task learning techniques along with width and center of windows [13] and fusing both 3-D dual path Conventional Neural Network and GBM [14].Using a noisy U-Net [15] improved neural network sensitivity and small nodule detection enhancement by creating a special noise for training in the hidden layer lung nodule identification can be done using various morphological features by training two models both RCNN and CNN to predict lung nodules in CT scan images [16]. Pre-processing CT scan images are done through blurring and thresholding so as to enhance the quality of the input and through splitting left and right lung to reduce the complexity the image and to increase accuracy in DCNN, is defined in [17]. Four different sized 3D CNN [18] also provide higher accuracy for detecting the lesions irrespective of their size.

III. Proposed Method

The proposed methodology employs three stages: Lung Cancer detection, segmentation and stage identification respectively. The first one is the lung cancer detection which will classify the lung CT images into benign or malicious and thus from the dataset abnormal lung CT can be extracted. The second component is malignant nodule segmentation which is used for extracting nodule portions from the malicious lung. The third component is lung cancer stage identification which will find out the stages of all nodes that have been segmented using UNet++ based on popular cancer staging standard named TNM staging which was developed by Union of International Cancer Control (UICC). Based on the size of the nodules(T), it is classified into different stages which will helps to diagnose patient's degree of spread of disease more accurately by an oncologist than previous existing methods. Overview of proposed method is shown in Fig. 1.

A. Lung Cancer Detection

Lung Cancer Detection is done using VGG-16 CNN which is shown in Fig. 2.

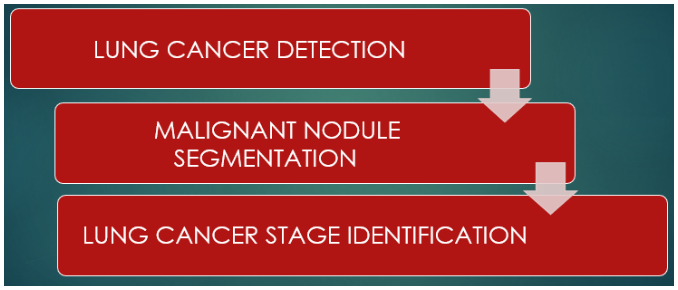


Fig. 1. Proposed Modules.

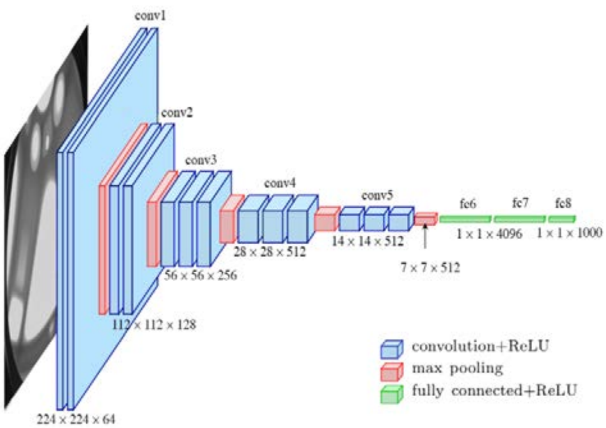


Fig. 2. VGG-16 Architecture (Source: [27]).

DCNN is used to detect lung cancer based on chest CT images [21]. Lung regions are extracted from CT images in the first stage. It is used to train the medical images and thus helps to diagnose the patient's disease. The main objective is to detect whether the CT of the lung is malignant or benign [23]. Here, VGG-16 is used for classification. In VGG architecture [20], filters are used by all convolutional layers with small receptive field of size 3x3. Convolutional layers are followed by max spatial pooling over 2x2 window and stride 2 which effectively down samples resolution by a factor 2. Two fully connected layers, each having 4096 channels, and layer with 2 sigmoid activated outputs corresponding to benign and malicious class are connected to the last pooling layer.

B. Malignant Nodule Segmentation

For nodule segmentation, U-net++ [22] architecture is used. Input for segmentation would be the malignant images that we got from previous module. Those images and its mask are generated and both are given as input for training the model. Training data contains 30 images which are not satisfactory to cater a deep learning neural network. So, data augmentation is done to increase the input samples for better training. Output obtained from the network represent mask from which learning should be done. The mask pixels should be in [0,1] range which is ensured by sigmoidal activation functions. In U-net++ architecture there is two parts namely the expansive and contraction path in which it poses series of nested convolution block to turn down the semantic gap in both encoder-decoder parts. Along with that, it can skip pathways which enable to prune network according to our requirements at any time. Architecture of UNet++ is shown in Fig. 3.

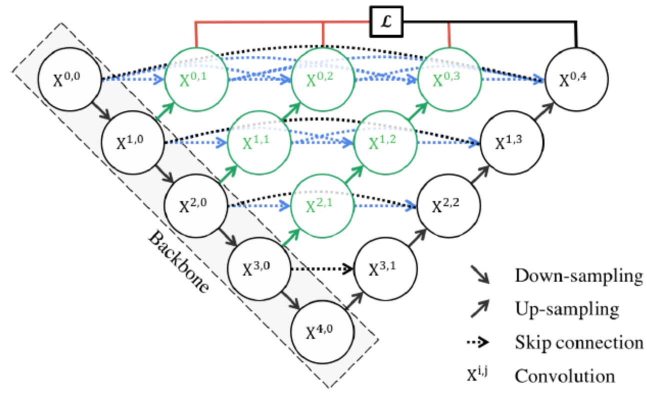


Fig. 3. UNet++ Architecture (Source: [28]).

In contracting path, each task account for two convolutional layers. The number of channels vary from 1 → 64 as convolution rises the depth of the image. The max pooling process halves down the image size owing to padding issues. But here padding= "same" and the process is repeated for 3 more times. 2 convolutional layers are built at the bottom part with no max pooling and as a result image has been resized. In the expansive path, image is upsized to its native size by using Transposed convolution. Padding operation is applied on the original image go around with a convolution operation. The image is upsized after transposed convolution and this image is merged with the corresponding image produced from the contracting path. More precise prediction can be achieved by combining information from the previous layers. Again, two other convolution layers are included. This process is repeated 3 more times. The last step is to reshape the image. The last layer is a convolution layer and having one filter with size 1x1.And the rest is same for neural network training. By giving any of the malicious input along with mask, testing is done which provide right segmented nodule. From the segmentation module, *.png* image will be generated as output.

C. Lung Cancer Stage Identification

Based on the area of malignant nodule, the stage of cancer can be identified. It will show how big the disease is, and will also help to find out whether it has spread to another part of our body. Stage identification is very important since it helps the doctor to diagnose the cancer into limited or extended. In order to accomplish this, TNM staging, a globally recognized standard is used to determine the spread of lung cancer. In TNM staging, three parameters are used to determine how severely the patient is affected. Parameters are T to denote size of the tumor; N to denote whether it has spread to lymph nodes and M denotes metastasis which indicates whether cancer have spread to different region or not. As for now, in this work only tumor size is taken into consideration with labels T1 to T4.

IV. Implementation

The trained system can detect presence of cancer in CT image of the lung and only the malignant image is given to U-Net++ for segmentation. From the segmented image stage identification is done i.e., stage labels like T1, T2, T3, T4. Fig. 4 shows the block diagram of the proposed system.

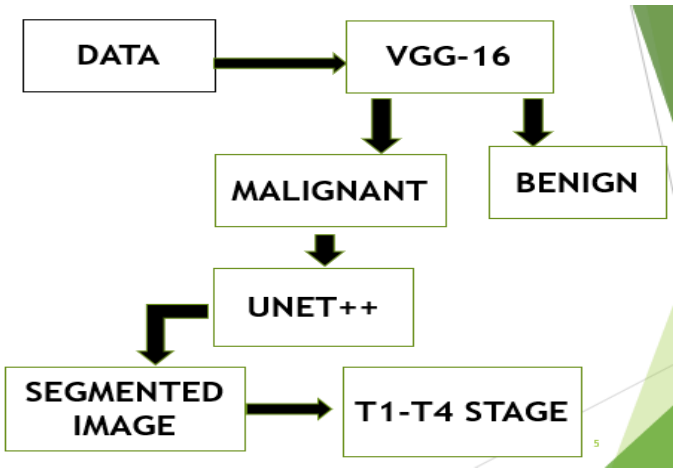


Fig. 4. Block Diagram.

Codes are executed in Google Collaboratory. This research tool is a Jupyter notebook environment runs on dedicated servers generally used for machine learning works. 2-core Xeon 2.2GHz processor, 33GB space, 13GB system memory and an NVDIA Tesla K80gpu are the features of Colab VM. Here, Keras on the TensorFlow background is used to run the code. Once the images are ready in its binary matrix format, dataset is split into three sets as training, validation and testing phase within the ratio 70%:15%:15%. In general, DNN requires large data set for train-testing, so data augmentation [19] is applied in order to obtain larger data set. For that various augmentation techniques like rotation, zoom, shear, flipping is done on the same images which can be used in the training process, and thus training algorithm can use a larger data set created at train time. Elements that have below 50% of success rate will be dropped out by Learning rate and the dropout factor. Dataset (X, Y) will be taken in training process and data set (X_Test, Y_Test) for testing. The algorithm passes all the images in every train cycle. Our training process has 100 epochs to train 200 large scale CT images with batch size 128. After the completion of training, the network is saved and can be used to separate CT images into benign or malignant. As activation function for the output layer, SoftMax is used and cross entropy as loss functions. In testing a single image or a group of images were fed to the trained model. For predictions, path will be for single image testing and for group testing limit is given.

Malicious lung along with its corresponding masks are taken as input for segmentation with its dimensions resized from 224*224 to 128*128. Training is done using U-NET++ architecture along with their corresponding mask and it may take between 10 to 20 minutes depending upon the systems performance. Training step can be 5 epoch which will be fair for configuration. And once the training is completed, model is created. For training, weight optimizer Adam and sigmoid activation function is used with batch size equals 32. For each convolution layer, kernel size is 3X3 and with a stride of 2. After each convolutional layer, required padding is added to keep the image size same. Overfitting in deep neural network will be avoided by using dropout factor. After segmentation of image, morphological operation is used to get the lung contour and to eliminate unnecessary parts. By doing morphological operations, it gets not only the lung but also apparent lung nodule. And then using the segmented nodule, nodule area is calculated. For that, according to the TNM staging standard for cancer detection, there is a particular threshold for labelling each nodule in different stages. The stages are from T1 to T4 and this will show how progressively cancer is affecting the lung. Each nodule stages size limit is shown in Table I.

TABLE I. THRESHOLD VALUES OF LUNG CANCER NODULES BASED ON SIZE IN TNM STAGING STANDARDS

STAGING	SUB-STAGING	NODULE SIZE
T1	T1(a)	Between 3mm and 10mm
	T1(b)	Between 10mm and 20mm
	T1(c)	Between 20mm and 30mm
T2	T2(a)	Between 30mm and 40mm
	T2(b)	Between 40mm and 50mm
T3	No Staging	Between 50mm and 70
T4	No Staging	Greater than 70mm

A. Dataset

The Lung Image Database Consortium and Image Database Resource Initiative (LIDC-IDRI) database, provide training dataset in DICOM format with common tags which include the patient's name, age, sex, occupation and DICOM Unique Identifiers (UIDs) to indicate the patient’s identity in DICOM which is put it into code within an image header. But considering the patient’s confidentiality, all information should be removed from the DICOM header when a DICOM file is uploaded for research purposes. So, an efficient method is by converting DICOM file into JPEG image format. Since JPEG format is small in size, have lossless compression, readable by all computer platforms and highly portable they are the best preferred format since images are transferred over the Web. LIDC and IDRI consists of CT scan lung images containing both normal as benign and abnormal as malignant [24].

V. EXPERIMENTAL RESULTS

Predictions are done from lung cancer detection module through training the model using VGG-16 with given test images to display the correct labels as benign or malignant. Validation is also done to know how well this model is adapting to unseen data. Each batch, training will calculate loss with target output and expected output. Then calculate gradient of loss with respect to the model parameters. Estimation of val_loss, val_accuracy, train_loss, train_accuracy is done in plot.png corresponding to 20,40,60,80,100 epoch. Validation loss and Training loss is gradually decreasing and Training accuracy and Validation accuracy is exponentially increasing and finally become stable which means the model built is learning and working fine. Fig. 5 shows the train_loss, val_acc, val_loss and train_acc obtained after training and validating the dataset. It yields 99.83% accuracy in classification.

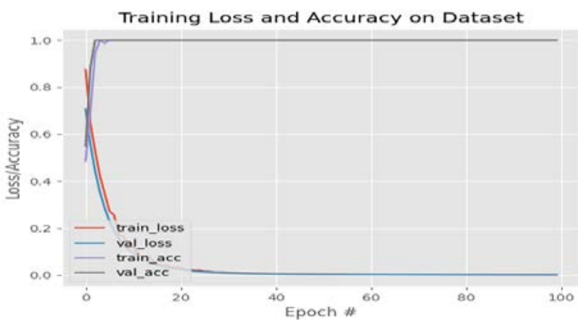


Fig. 5. Lung Cancer Prediction Result.

The result of lung cancer detection will be as benign or malignant based on the score values of each CT which is shown in Table II.

For nodule segmentation, input (malignant lung obtained after lung cancer detection module) and their corresponding mask will give the right segmentation result is shown in Fig. 6.

After segmentation contour along with pulmonary nodule is segmented using UNet++ which is shown in Fig. 7.

TABLE II. SCORE VALUES OBTAINED AFTER LUNG CANCER PREDICTION

LABELS	BENIGN	MALIGNANT
NON-CANCEROUS	0.998	0.001
CANCEROUS	0.002	0.988

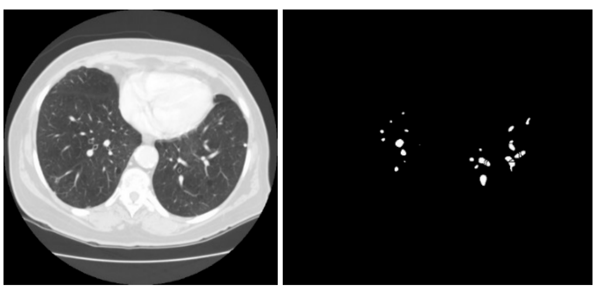


Fig. 6. Image and Corresponding Mask.

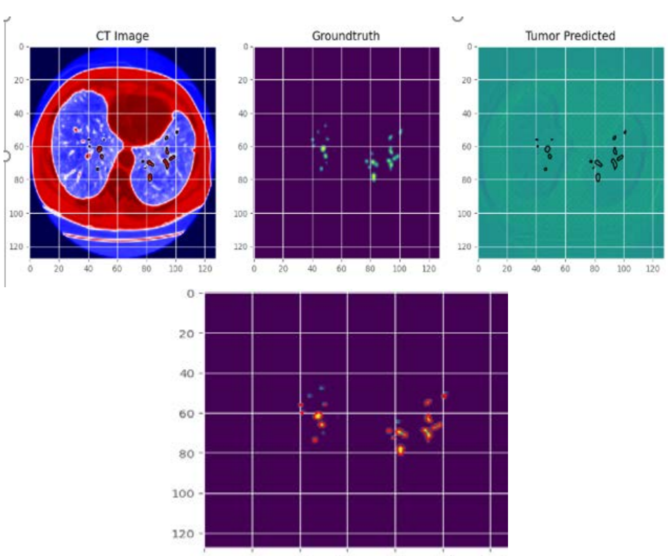


Fig. 7. Segmented Nodule.

After segmenting all nodules from malignant CT by UNet++, stages of segmented nodules are found by calculating the diameter of nodules present in the cancerous CT's. All nodules size between 3mm and 10mm is shown as red color in Fig. 8.

Here, two nodes are present in T1(a) stage. The corresponding nodules say nodule 1 and nodule 2's diameter is 4mm and 5.5mm respectively which is between 3mm and 10mm. So, it lies in T1(a) Stage and is shown in Fig. 9.

Nodule's size between 10mm and 20mm is shown in red spot in Fig. 10.

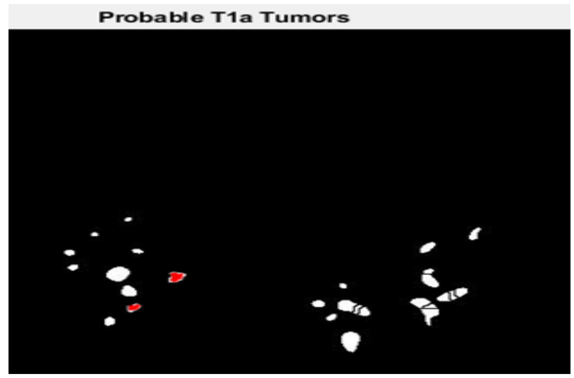
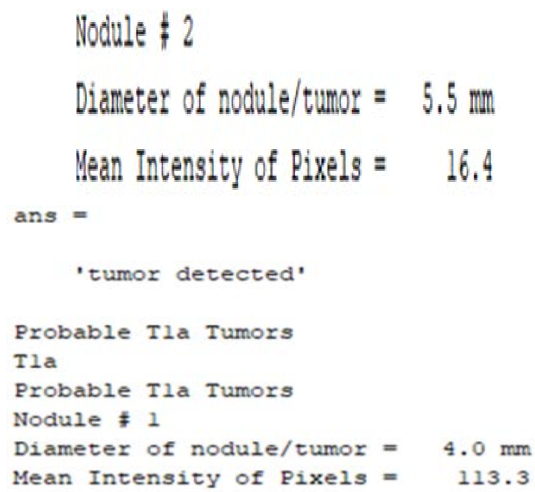


Fig. 8. Nodules Detected in T1(a) STAGE.



```
Nodule # 2
Diameter of nodule/tumor =   5.5 mm
Mean Intensity of Pixels =    16.4
ans =
    'tumor detected'
Probable T1a Tumors
T1a
Probable T1a Tumors
Nodule # 1
Diameter of nodule/tumor =    4.0 mm
Mean Intensity of Pixels =    113.3
```

Fig. 9. Each Nodule in T1(a) STAGE.

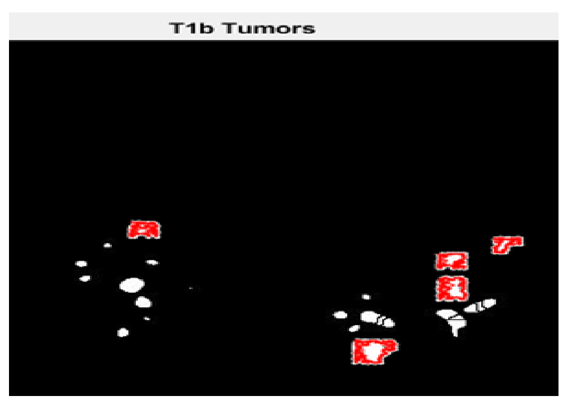


Fig. 10. Nodules Detected in T1(b) STAGE.

Here, five nodes are present in T1(b) stage which is shown in the above result in red color. The corresponding nodules say nodule1, 2, 3, 4, 5's diameter is 10.8mm, 15.3mm, 10.7mm, 14.8mm, 11.8mm respectively which is between 10mm and 20mm.So it lies in T1(b) Stage and each nodules size will be shown in Fig. 11.

Nodule's size between 20mm and 30mm is shown in green spot in Fig. 12.

```
Probable T1b Tumors
T1b
Probable T1b Tumors
Nodule # 1
Diameter of nodule/tumor =  10.8 mm
Mean Intensity of Pixels =     34.8

Nodule # 2
Diameter of nodule/tumor =  15.3 mm
Mean Intensity of Pixels =    136.2

Nodule # 3
Diameter of nodule/tumor =  10.7 mm
Mean Intensity of Pixels =    103.5

Nodule # 4
Diameter of nodule/tumor =  14.8 mm
Mean Intensity of Pixels =    122.9

Nodule # 5
Diameter of nodule/tumor =  11.8 mm
Mean Intensity of Pixels =    113.8
```

Fig. 11. Each Nodule in T1(b) STAGE.

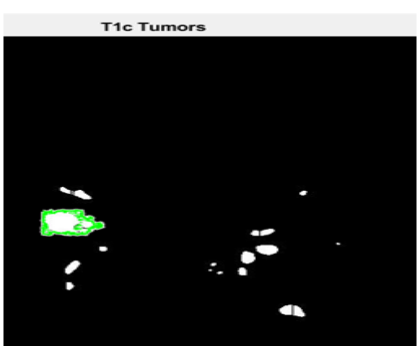


Fig. 12. Nodules Detected in T1(c) STAGE.

Here, one node is detected in T1(c) with size 26.5mm which is between 20mm and 30mm is shown in Fig. 13.

```
Probable T1cTumors
Probable T1c Tumors
T1c
Nodule # 1
Diameter of nodule/tumor =  26.5 mm
Mean Intensity of Pixels =    180.6
```

Fig. 13. Nodule in T1(c) STAGE.

Nodules size greater than 70mm is shown in yellow spot in Fig. 14.

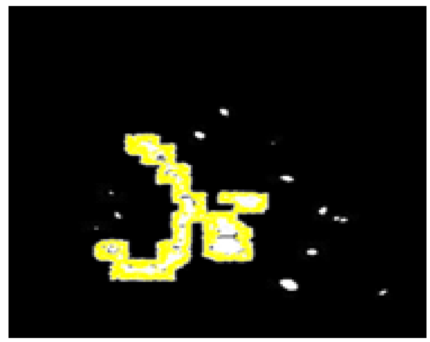


Fig. 14. Nodules Detected in T4 STAGE.

Here, one node is detected in T4 with size 73.9mm which is greater than 70mm is shown in Fig. 15.

```
Nodule # 1
Diameter of nodule/tumor =  73.9 mm
Mean Intensity of Pixels =    127.6
```

Fig. 15. Nodule in T4 STAGE.

These staging helps oncologist to find whether a patient should go for a surgical staging or non-adjuvant staging treatment which includes either chemo-therapy or target drug radiation treatment. So, it helps doctor to diagnose the disease with much more ease than before since early detection was done through manual interpretation of 300 cross-sectional CT images which has been taken from a single CT detector.

VI. Conclusion

With the advent of the pattern recognition and machine learning, data scientists have proposed many approaches which were robust in finding the hidden patterns and reducing the false positives. With this, as the data for the patients detected with lung cancer increased, the CT scans tend to differ more significantly from each other, across patients. Thus, several approaches are being proposed to overcome the challenges to detect the pulmonary nodules and thus increases the chances of the survival of the patients. With the advancement of Technology and Computer Aided Diagnosis, a lot of automated systems are introduced to address the issue of reducing false positive while estimating the presence of pulmonary nodules in the CT scans of the patients. From here, we have the opportunity to use current topics to identify hidden patterns in nodules and construct a model to increase the probability of malignant tumor detection along with the identification of different stages of cancer. In future, parameters like whether malignancy have spread to other parts of the body(M) and whether it affects to the lymph nodes(N) can also be considered along with the tumor size(T) as parameters for lung cancer stage identification which will give much more accuracy in finding stages.

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Classification Model of Municipal Management in Local Governments of Peru based on K-means Clustering Algorithms

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***Abstract*—The K-means algorithm groups datasets into different groups, defines a fixed number of clusters, iteratively assigning data to the clusters formed by adjusting the centers in each cluster. K-means algorithm uses an unsupervised learning method to discover patterns in an input data set. The purpose of the research is to propose a municipal management classification model in the municipalities of Peru using a K-means clustering algorithm based in 58 variables obtained from the areas of human resources, heavy machinery and operating vehicles, information and communication technologies, municipal planning, municipal finances, local economic development, social services, solid waste management, cultural, recreational and sports facilities, public security, disaster risk management, environmental protection and conservation of all the municipalities of the 24 departments of Peru and the constitutional province of Callao. The results of the application of the K-means algorithm show that 32% of the municipalities made up of the municipal governments of Amazonas, Apurímac, Huancavelica, Huánuco, Ica, Lambayeque, Loreto and San Martin; are in Cluster 1; the 8% in Cluster 2 with the municipal governments of Ancash and Cusco; in the third Cluster the 28% with the municipal governments of the constitutional Province of Callao, Madre de Dios, Moquegua, Pasco, Tacna, Tumbes and Ucayali and in Cluster 4, 32% composed of the municipal governments of Arequipa, Ayacucho, Cajamarca, Junín, La Libertad, Lima, Piura and Puno Region.**

Keywords—K-means; cluster; municipality; model; municipal management

I. Introduction

The clustering problem is one of the most studied topics in the data mining and machine learning communities. There is a wide variety of applications in social networks problems, multimedia, social science, health, education and other fields of knowledge. Grouping is a diverse topic, and the underlying algorithms are highly dependent on the data domain and the scenario in which the problems occur. The objective of clustering is to classify a set of elements into groups that are very similar among them, but different with elements from other groups. Author in [1] consider the k-Means grouping algorithm, to be one of the most efficient grouping algorithms for large-scale data sets.

The K-means algorithm allows clustering by grouping objects into k groups, this is why it becomes very important for researchers and so its results, which will be used in the municipalities of Peru that promote local development, but also adapting themselves to current organizations' real situation; mainly with the objective to improve the provision of local public services; consequently it will allow a continuous improvement in the offered services.

The current investigation states the development of a model based on the K-means algorithm. It proposes an adjustment of the grouping algorithm, focusing on the detection of behavior patterns, for that it needs to read Peruvian municipalities databases with 58 variables, allowing the decision-making process to improve in all the levels.

Provincial and district municipalities are the governing bodies that promote local development, with legal status under public law and full capacity to fulfill their purposes (Law No. 27972 - Organic Law of Municipalities). Local governments are classified according to their jurisdiction: provincial municipality, located on the territory of the respective province and the provincial capital district. District municipality, located on the territory of the district and town center municipality, whose jurisdiction is determined by the respective provincial council.

The National Institute of Statistics and Informatics – INEI has statistical information of the provincial, district, and population centers at the national level, in order to generate municipal indicators that support regional and local management for planning and proper decision-making. Information that has been used in the investigation of the 196 provincial municipalities, 1,678 district municipalities and 2,656 municipality of populated centers of the country, compiled in the National Register of Municipalities 2019 [2]. The factors considered in the study are related to human resources, heavy machinery and operational vehicles, information and communication technologies, municipal planning, municipal finances, local economic development, social services, solid waste management, cultural, recreational and sports facilities, public security, disaster risk management and environmental protection and conservation.

The purpose of the research is to propose a classification model for municipal management of local governments in Peru based on K-means clustering algorithms, at the same time evaluating the characteristics of local governments in every cluster.

This article is organized as follows: The second section is a review of some studies on the k-means algorithm and municipalities features. The next section focuses on the theoretical background. Section fourth shows the results of the research, while the fifth part presents the argumentation of the results. Finally, the conclusion of the research, which proposes some ideas for further investigation, are shown in section sixth.

II. Related Works

This section presents the references of different investigations related to K-means and municipal management.

In [3] two grouping algorithms are compared, centroid K-Means algorithms and Fuzzy C-Means, based on their grouping efficiency, the conclusion states the K-Means algorithm is better than the Fuzzy C-Means algorithm, and considers they can be used to discover association rules and functional dependencies.

Customer segmentation is the subdivision of a business customer database into groups called customer segments, so that each customer segment consists of clients who share similar market characteristics. In [4] the k-Means grouping algorithm has been applied in customer segmentation in a retail business, identifying four steady groups or customer segments.

In [5] proposes a better K-Means algorithm to improve the classification precision, when K-Means cannot adequately classify data under certain data distribution conditions. The proposal considers the effect of variance on the classification so that the data can be classified with greater exactness.

In [6] presents a data model capable of extracting, classifying and then mapping data in order to generate new, more structured data that meets the organization's needs. This arrangement is based on the K-means grouping algorithm.

Data recording on the Internet is a way of Big Data to use the K-Means technique as a solution to the analysis of user's behavior. [7] In this research, a grouping process has been carried out using the K-means algorithm, an algorithm that classifies users into three groups, high, medium and low. The result of the research shows that each of these groups visits frequently some websites, through search engines, social networks, and news and information.

In [8], a balanced K-means grouping algorithm is proposed to classify apples automatically. The results show the precision of the multiple characteristics classification method is more than 96%. [9] Grouping is a data analysis technique that is used to investigate the underlying structure of the data. It is described as the technique that groups objects which have similar characteristics.

It suggests a methodology to investigate the inherent patterns in the relationships between air traffic and macroeconomic development. To do so, it uses data mining techniques, including the grouping of K-means. The most important contribution in the methodology is the ability to select variables objectively and quickly [10].

In [11] four groups of municipalities were identified based on socioeconomic indicators. The purpose was to examine the socioeconomic differences among Slovenian municipalities and classify them into relatively homogeneous groups. The classified groups based on socioeconomic indicators reflect their development features, the results confirm the fact that the eastern part is less developed meanwhile the western part is the most developed in Slovenia. There is a small group of municipalities where the socioeconomic situation is grave.

In [12] the purpose was to identify municipalities where aspirations for energy autonomy could make technical and economic sense, consequently replicate successful projects in other municipalities within the same group; a cluster analysis to establish a municipal typology is used, in order to analyze the techno-economic municipalities appropriateness, for the autonomous energy systems. The results identify municipalities which successful measures from other municipalities can be applied to and provide a basis for future energy studies around the country.

III. Theoretical Background

The K-Means technique is an unsupervised clustering algorithm, used with large amounts of data. The objective of the K-Means algorithm is to find "K" groups (clusters) among the data set. This algorithm is a grouping technique that is used in different machine learning applications [13] [14].

The K-means clustering algorithm [9] has been discovered more than 50 years ago by Steinhaus (1956), since then it has been applied in various fields of knowledge such as marketing, psychology, medicine, social sciences and biology, becoming one of the most widely used methods for its simplicity, easy implementation and efficiency [15].

The K-Means algorithm works iteratively by assigning each row of the input data set to one of the "K" groups based on their characteristics. The columns (variables) are grouped considering the similarity. The result of running the algorithm is:

- Each group centroids are coordinates of each K set that will be used to label new data sets.
- Labels for the training dataset. Each tag belongs to one of the K clusters formed.

The clusters adjust to a new position in each iteration of the process, until the algorithm converges. Once the centroids have been found, the data must be analyzed to observe which characteristics are unique, regarding the other groups. These groups are the labels that the algorithm generates.

A. *K-Means Algorithm*

The K-means algorithm begins by specifying a set of initial cluster centers that are derived from data. Then assigns the data to the most similar cluster, based on the input variables values. After all cases have been assigned, the cluster centers are updated to reflect the new dataset assigned to each cluster. Then the records are checked once more to see if they need to be reassigned to a different group, and the data allocation and iteration process continues until the maximum number of iterations is reached or the change between one iteration and the next does not exceed a specified threshold. Depending on the similarity or dissimilarity characteristics, data sets are grouped into several different groups, for similar data within the same group and for different data among groups [16].

The K-means algorithm is one of the most important unsupervised clustering algorithms [17] that produces high quality results in less computation time [1]. The K-means machine learning algorithm [18] is used to group a known, assumed, or indicated in advance dataset. In [5] K-means is a classic prototype-based partitioning grouping technique that attempts to group data into k groupings that have been specified by the user.

Steps for executing K-means clustering algorithms [4] [5]

1) Define the cluster number, k.
2) Initialize the k centroids of the group.
3) Assign the n data points to the closest clusters.
4) Update the centroids of each group.
5) Repeat steps 3 and 4 until there are no more changes in the positions of the centroids.

[19] The k-means algorithm is one of the most widely used grouping algorithms, it is designed to group numerical data, in which each grouping contains a center called centroid. The algorithm works with cases in which all the variables are the quantitative type, and the Euclidean quadratic distance [20].

$$\mathrm{d}(\mathrm{x_i}, \mathrm{x_i'}) = \sum_{\mathrm{j}=1}^{\mathrm{p}} \left(\mathrm{x_{ij}} - \mathrm{x_{i'j}}\right)^2 = \left\|\mathrm{x_{ij}} - \mathrm{x_{i'j}}\right\|^2 \quad (1)$$

it is chosen as a difference measurement. Take into account the weights in the Euclidean distance can be used by redefining the x_{ij} values.

The scatter points can be written as:

$$W(C) = \sum_{k=1}^{K} \sum_{C(i)=k} \sum_{C(i')=k} \|x_i - x_{i'}\|^2 \quad (2)$$

$$W(C) = \sum_{k=1}^{K} N_k \sum_{C(i)=k} \|x_i - \bar{x}_{i'}\|^2 \quad (3)$$

In the k-means algorithm, the sum of the squares of the Euclidean distances of data points to their closest representatives, is used to quantify the objective function of the clustering [20]. Therefore, we have:

$$Dist\left(\bar{X}_i, \bar{Y}_j\right) = \left\|\bar{X}_i - \bar{Y}_j\right\|^2 \quad (4)$$

where $\bar{x}_k = \left(\bar{x}_{1k}, \dots, \bar{x}_{pk}\right)$, is the vector of means associated with the k-th cluster, and $N_k = \sum_{i=1}^{N} I\left(C(i) = k\right)$. Thus, the criterion is to give the N observations to the K clusters so within each cluster the average of the differences of each observation to the mean of the cluster, defined by the cluster points, might be minimal.

IV. Results

This section shows the classification of municipal management in Peru local governments, after applying the K-Means Clustering algorithm.

A. Research Variables

58 variables have been used that have been gotten from the areas of human resources, heavy machinery and operational vehicles, information and communication technologies, municipal planning, municipal finances, local economic development, social services, solid waste management, cultural, recreational and sports facilities, public security, disaster risk management, protection and conservation of the environment of all local governments in the 24 departments of Peru and the constitutional province of Callao. The variables were the following:

- Municipal staff
- Female municipal staff
- Male municipal staff
- Technical assistance requirements
- Training requirements
- Heavy Operating Machinery
- Vehicles and Equipment
- Operating Computers
- Internet access
- Standard Transparency Portal
- Telephone lines installed and in service
- Urban and / or rural management and development instruments
- Sole Code of Administrative Procedures
- Method of payment of taxes and / or services
- Coercive Execution office
- Municipal revenue collected at departmental level
- Current income
- Capital income
- Transfers
- Financing
- Municipal expenses executed
- Capital expenditures
- Donations and capital transfers
- Debt Service
- Operating licenses for business
- Building permits
- Activities to promote Micro and Small Businesses
- Activities to promote crafts
- Social Organizations
- Care Center for the Elderly (CIAM)
- Municipal Office of Attention to People with Disabilities (OMAPED)
- Municipal Ombudsman offices for Children and Adolescents (DEMUNA)

- Municipalities that collected solid waste (garbage)
- Daily average amount of solid waste collection
- Solid waste management instruments
- Number of users served at the Municipal Library
- Number of visitors / users to culture centers
- Number of visitors / users to theaters
- Number of visitors / users to museums
- Municipal police force
- Female Municipal police force
- Male Municipal police force
- Interventions registered by the Municipal police force
- Equipment and infrastructure for Municipal police force activities
- Dividing by sectors for patrolling activities
- Integrated patrol of municipal police force with the Peruvian Police force
- District Citizen Security Committee (CODISEC)
- Citizen Security Plan
- Disaster Risk Management Working Groups (GTGRD)
- National Civil Defense System Platform (PDC)
- Municipal Emergency Operations Center (COEL)
- Results-based budgeting Program N ° 068
- Natural and man-made hazards
- Municipalities with an Environmental Office or Unit
- Registered environmental complaints
- Elements that cause environmental pollution
- Environmental management instruments available in the municipality
- Actions carried out by the municipality to encourage environmental conservation

B. *K-Means Clustering Algorithm*

The K-Means Clustering algorithm used has the following characteristics:

- Number of clusters: 4
- Variables: 58

Build Settings

- Generate distance field: true
- Cluster label: String
- Label prefix: cluster
- Optimize: Memory
- Mode: Expert
- Stop on: Default

Training Summary

- Algorithm: K-means
- Model type: Clustering

Fig. 1 shows the K-means algorithm used to establish the classification of municipal management in local governments in Peru.

C. *K-Means Clustering Algorithm Results*

Fig. 2 shows the classification of local governments by department. The K-Means algorithm considers that the 32% (8) of the local governments divided by departments in Peru is in cluster 1, the 8% (2) of them to cluster 2, the 28% (7) to cluster 3 and to cluster 4 another 32 % (8).

Fig. 3 shows the intensity of membership of the departments in the groups formed by K-means clustering.

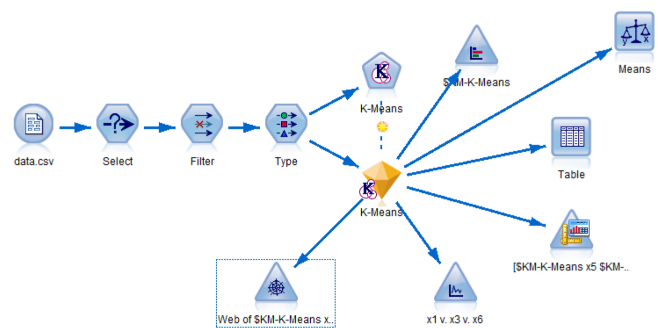

Fig. 1. K-Means Clustering Algorithm.

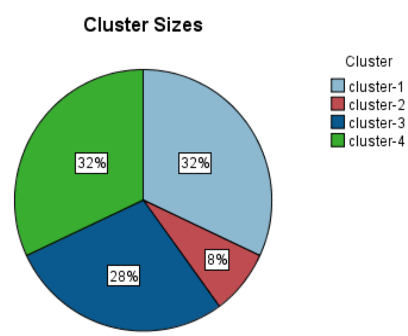

Fig. 2. Cluster Sizes using the K -Means Clustering Algorithm.

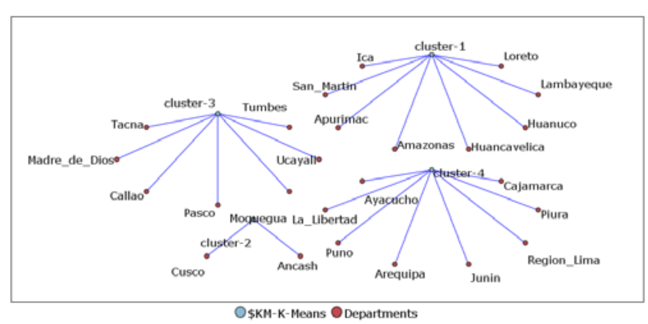

Fig. 3. Membership of Departments to Groups Formed by K -means Clustering.

D. Evaluation and Validation of the Algorithm

The K-means clustering algorithm shows the classification of municipal management in the local governments of Peru in 4 clusters:

Table I shows that in cluster 1 there is an average of 4898 workers per department, of which 1623 are female and 3265 are male. In cluster 2, on average there are 19796 workers per department, 5857 of which are female and 13939 are male. Cluster 3 has an average of 3,578 workers per department, divided in 1,423 female workers and 2,155 male employees. Cluster 4 averaged 9075 workers per municipality, of which 3077 were female and 5998 males. Likewise, it is observed that 62 municipalities require technical assistance in cluster 132 municipalities in cluster 16 municipalities in cluster 3, and 99 municipalities in cluster 4. It is also shown that 67 municipalities in cluster 135 in cluster 17 in cluster 3 and 104 in Cluster 4 requires training.

According to Table II, it can be seen that in cluster 1, 37 municipalities have at least heavy operating machinery and 65 municipalities have vehicles and equipment. In cluster 2 shows that 98 municipalities have at least heavy operating machinery and 133 municipalities with vehicles and equipment. Cluster 3 describes that 13 municipalities have at least heavy operating machinery and 18 have vehicles and equipment. In cluster 4 there are 76 municipalities that at least have one heavy operating machinery and 104 with vehicles and equipment.

Table III shows that in cluster 1 there are 2,117 computers on average per department, of which 1,812 have internet access and 23 municipalities have their transparency portal. Cluster 2 shows 7126 operating computers on average by department of which 5716 with internet access and 41 municipalities with its transparency portal. Cluster 3 presents an average of 1,513 operating computers per department with 1,219 computers with internet access and 10 municipalities with its transparency portal. Cluster 4 shows 4049 operating computers of which 3604 have internet access and with 37 municipalities that have their transparency portal.

According to Table IV it is observed in cluster 1 that on average 65 municipalities have at least one management instrument, among which the Organizations and Functions Regulation stands out, and 49 municipalities have the Sole Code of Administrative Procedures (TUPA). In cluster 2, an average of 127 municipalities have a management instrument and 100 municipalities have the Sole Code of Administrative Procedures (TUPA). Cluster 3 shows that on average 17 municipalities have a management instrument and 15 municipalities have the Sole Code of Administrative Procedures (TUPA). Cluster 4 shows that on average 94 municipalities have at least one management instrument and 76 municipalities have the Sole Code of Administrative Procedures (TUPA).

According to Table V, from the total municipal income collected it is observed that in cluster 1 the 46% is from Central Government transfers, financing 42%, current Income 12% and capital Income 0,03%. Cluster 2 shows that 67% corresponds to transfers from the Central Government, 25% to financing, 8% to current income and 0.07% to capital income. In cluster 3 it is seen that 51% comes from transfers from the Central Government, 29% to financing, current income 20% and capital income 0.42%. Cluster 4 shows that 50% corresponds to transfers, 36% to financing, 14% to current income and 0.12% to capital income.

TABLE I. HUMAN RESOURCES

Variable	**Cluster 1**	**Cluster 2**	**Cluster 3**	**Cluster 4**
	8 Records	2 Records	7 Records	8 Records
Municipal staff				
Mean	4898	19796	3578	9075
Standard deviation	1602	14750	2280	2327
Technical assistance requirements				
Mean	62	132	16	99
Standard deviation	20	41	8	22
Training requirements				
Mean	67	135	17	104
Standard deviation	22	35	9	23

TABLE II. HEAVY MACHINERY AND OPERATING VEHICLES

Variable	**Cluster 1**	**Cluster 2**	**Cluster 3**	**Cluster 4**
	8 Records	2 Records	7 Records	8 Records
Heavy Operating Machinery				
Mean	37	98	13	76
Standard deviation	13	7	7	18
Vehicles and Equipment				
Mean	65	133	18	104
Standard deviation	20	32	8	20

TABLE III. INFORMATION AND COMMUNICATION TECHNOLOGIES

Variable	**Cluster 1**	**Cluster 2**	**Cluster 3**	**Cluster 4**
	8 Records	2 Records	7 Records	8 Records
Operating Computers				
Mean	2117	7126	1513	4049
Standard deviation	412	3722	706	692
Internet access				
Mean	1812	5716	1219	3604
Standard deviation	404	2563	543	765
Standard Transparency Portal				
Mean	23	41	10	37
Standard deviation	7	0	4	8

TABLE IV. MUNICIPAL PLANNING

Variable	**Cluster 1**	**Cluster 2**	**Cluster 3**	**Cluster 4**
	14 Records	2 Records	8 Records	1 Records
Urban and / or rural management and development instruments				
Mean	65	127	17	94
Standard deviation	21	33	8	20
Single Text of Administrative Procedures				
Mean	49	100	15	76
Standard deviation	14	24	6	16

TABLE V. MUNICIPAL FINANCE

Variable	Cluster 1	Cluster 2	Cluster 3	Cluster 4
	8 Records	2 Records	7 Records	8 Records
Municipal revenue collected at the departmental level				
Mean	726562	2626041	405445	1359223
Standard deviation	151935	490451	190745	382405
Municipal expenses executed				
Mean	674408	2051009	349766	1178082
Standard deviation	129651	751169	184323	294256

On the other hand, in cluster 1 it is shown that 63% of the expenses executed in the municipalities were spent capital expenses, cluster 2 shows 67%, in cluster 3 42% to capital expenses and in Cluster 4 the municipalities allocated 59% to capital expenses.

Table VI shows in cluster 1 the number of operating licenses for establishments granted by local governments was in average 1,564 licenses, in construction 1,551 licenses and 37 municipalities reported that they carried out activities to promote Micro and Small Businesses. In cluster 2, 2,821 operating licenses were granted, 1,230 for construction, and 76 municipalities reported that they carried out actions Activities to promote Micro and Small Businesses. In cluster 3, were granted 751 operating licenses, 407 building permits, and 11 municipalities reported that they carried out actions to promote Micro and Small Businesses. Cluster 4 shows 2967 operating licenses granted, 2444 building permits, and 62 local governments carried out activities to encourage Micro and Small Businesses.

According to Table VII, it is shown that in cluster 1 there are an average of 87,206 users in social organizations (glass of milk, soup kitchen, mothers' club and youth organizations), 4841 beneficiaries in the Care Center for the Elderly (CIAM), 6126 People with Disabilities and an average of 4387 cases attended each year in the Municipal Ombudsman for Children and Adolescents (DEMUNA). Cluster 2 shows an average of 118,281 users in social organizations, 9,133 beneficiaries in the Care Center for the Elderly, 9,190 people with disabilities and 17,257 cases on average attended each year by the Municipal Ombudsman for Children and Adolescents. Cluster 3 shows 34,890 users on average in social organizations, 3,307 CIAM beneficiaries, 3,153 people with disabilities and 5,626 cases attended on average by DEMUNA. Cluster 4 shows an average of 138087 users in social organizations, 11,768 beneficiaries of CIAM, 9,512 people with disabilities and 9,123 cases attended by DEMUNA.

Table VIII shows that 67 municipalities collect solid waste, on an average of 411,894 kilos per department in cluster 1. In cluster 2, there are 137 municipalities that collect solid waste, with an average amount of 742400 kilos per department. In cluster 3 there are 18 municipalities that collect solid waste, with an average amount of 297,729 kilos per department. Cluster 4 shows 104 municipalities that collect solid waste, with an average amount of 816506 kilos per department.

Table IX shows in cluster 1, the number of users served in the municipal library was 23075 users on average, 2741 users in cultural centers, in theaters 2471 and in museums 1795 users. In cluster 2, 103883 users were served in the municipal library, 19630 users in cultural centers, 79457 users in the theaters and in museums 45623 users. Cluster 3 served 5881 users in the municipal library, in cultural centers 2472 users, in the theaters 7649 and in museums 4768 users. In cluster 4 the municipal library served 73529 users, 13133 users in the House of Culture, in theaters 13917 users and in museums 14930 users.

TABLE VI. LOCAL ECONOMIC DEVELOPMENT

Variable	Cluster 1	Cluster 2	Cluster 3	Cluster 4
	8 Records	2 Records	7 Records	8 Records
Operating licenses for establishments				
Mean	1564	2821	751	2967
Standard deviation	553	327	467	1045
Building licenses				
Mean	1551	1230	407	2444
Standard deviation	1321	415	215	1776
Actions to encourage Micro and Small Businesses				
Mean	37	76	11	62
Standard deviation	19	35	6	10

TABLE VII. SOCIAL SERVICES

Variable	Cluster 1	Cluster 2	Cluster 3	Cluster 4
	8 Records	2 Records	7 Records	8 Records
Social Organizations				
Mean	87206	118281	34890	138087
Standard deviation	30068	1237	27987	54310
Comprehensive Care Center for the Elderly (CIAM)				
Mean	4841	9133	3307	11768
Standard deviation	1896	2819	3451	5174
Municipal Office of Attention to Persons with Disabilities (OMAPED)				
Mean	6126	9190	3153	9512
Standard deviation	2894	4924	2019	5975
Municipal Ombudsman for Children and Adolescents (DEMUNA)				
Mean	4387	17257	5626	9123
Standard deviation	1406	7640	9094	4880

TABLE VIII. PUBLIC CLEANING

Variable	Cluster 1	Cluster 2	Cluster 3	Cluster 4
	8 Records	2 Records	7 Records	8 Records
Municipalities that carried out solid waste collection (garbage)				
Mean	67	137	18	104
Standard deviation	21	35	8	22
Average daily amount of solid waste collection				
Mean	411894	742400	295553	816506
Standard deviation	282801	32446	297729	394566

TABLE IX. CULTURAL, RECREATIONAL AND SPORTS INFRASTRUCTURE

Variable	Cluster 1	Cluster 2	Cluster 3	Cluster 4
	8 Records	2 Records	7 Records	8 Records
Number of users served in the municipal library				
Mean	23075	103883	5881	73529
Standard deviation	20759	8190	7185	83444
Number of visitors / users to culture houses				
Mean	2741	19630	2472	13133
Standard deviation	2695	27675	3661	11642
Number of visitors / users to theaters				
Mean	2471	79457	7649	13917
Standard deviation	2971	32311	15970	23538
Number of visitors / users to museums				
Mean	1795	45623	4768	14930
Standard deviation	1869	47324	10916	13030

Table X shows in cluster 1 an average of 401 Municipal police force by department, 13% female, 87% male, and an average of 3,283 interventions by department were performed. Cluster 2 shows an average of 1313 Municipal police force troops, 14% female, 86% male, performed 11086 interventions. Cluster 3 shows an average of 359 serenade personnel by departments, 18% female, 82% male, and carried out 9486 interventions. Cluster 4 presents 1040 Female municipal police force troops on average by department, 12% female, 88% male, and performed 24146 interventions.

Table XI shows in cluster 1, that 52 municipalities have working groups for disaster risk management, an average of 52 municipalities have National Civil Defense System Platform and 21 with local emergency operations centers. Cluster 2 shows that on average 109 municipalities have working groups for disaster risk management, 111 municipalities have National Civil Defense System Platform and 56 have local emergency operations centers. Cluster 3 shows 14 municipalities that have working groups for disaster risk management, 15 municipalities National Civil Defense System Platform, and 8 that have local emergency operations centers. Cluster 4 shows 74 municipalities with disaster risk management working groups, 76 municipalities with Civil defense platforms and 35 with local emergency operations centers.

In Table XII it is observed that in cluster 1, 43 municipalities have an environmental office or unit, 23 municipalities received environmental complaints, 49 municipalities carried out actions to encourage environmental conservation. Cluster 2, shows 67 municipalities with an environmental unit, 38 of them have gotten environmental complaints and 88 municipalities carried out actions to conserve the environment. While in cluster 3, 14 municipalities have an environmental unit, 6 have received environmental complaints and 13 carried out actions to conserve the environment. Cluster 4 shows 66 municipalities with an environmental unit, 35 received complaints and 73 carried out actions to conserve the environment.

E. Classification Results

Fig. 4 shows the classification of municipal management in the local governments of Peru in the 24 departments and the constitutional province of Callao, resulting from the application of the K-Means clustering algorithm.

TABLE X. CITIZEN SECURITY

Variable	Cluster 1	Cluster 2	Cluster 3	Cluster 4
	8 Records	2 Records	7 Records	8 Records
Serenade cash				
Mean	401	1313	359	1040
Standard deviation	253	293	392	427
Female serenade cash				
Mean	51	181	66	126
Standard deviation	47	71	93	54
Male serenade cash				
Mean	350	1133	293	914
Standard deviation	214	221	301	377
Interventions registered by the serenade				
Mean	3283	11086	9486	24146
Standard deviation	2015	2879	10300	19387

TABLE XI. DISASTER RISK MANAGEMENT

Variable	Cluster 1	Cluster 2	Cluster 3	Cluster 4
	8 Records	2 Records	7 Records	8 Records
Disaster Risk Management Working Groups (GTGRD)				
Mean	52	109	14	74
Standard deviation	14	1	7	11
Civil Defense Platform (PDC)				
Mean	52	111	15	76
Standard deviation	14	8	7	10
Local Emergency Operations Center (COEL)				
Mean	21	56	8	35
Standard deviation	8	6	3	17

TABLE XII. PROTECTION AND CONSERVATION OF THE ENVIRONMENT

Variable	Cluster 1	Cluster 2	Cluster 3	Cluster 4
	8 Records	2 Records	7 Records	8 Records
Municipalities that have an Environmental Office or Unit				
Mean	43	67	14	66
Standard deviation	15	13	6	14
Registered environmental complaints				
Mean	23	38	6	35
Standard deviation	10	13	2	7
Actions carried out by the municipality to encourage environmental conservation				
Mean	49	88	13	73
Standard deviation	13	15	6	13

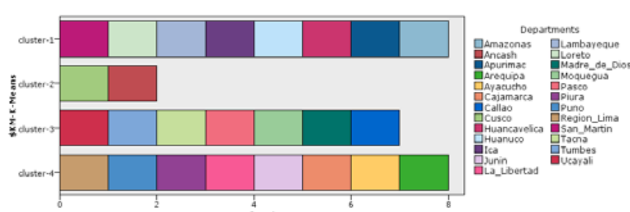

Fig. 4. Classification of Municipal Management in Local Governments of Peru.

V. Discussion

The local governments of the departments of Peru have been distributed as follows:

1) Cluster 1: Formed by municipal governments of 8 departments: Amazonas, Apurímac, Huancavelica, Huánuco, Ica, Lambayeque, Loreto and San Martin.

2) Cluster 2: Formed by municipal governments of Ancash and Cusco.

3) Cluster 3: Formed by municipal governments of 7 departments: Constitutional Province of Callao, Madre de Dios, Moquegua, Pasco, Tacna, Tumbes and Ucayali.

4) Cluster 4: Formed by municipal governments of 8 departments: Arequipa, Ayacucho, Cajamarca, Junín, La Libertad, Region Lima, Piura and Puno.

From 100% of the local governments of the departments of Peru, it is observed that 32% of them are in Group 1, 8% in Group 2, 28% in the Third Group and 32% are found in Group 4. In [11] the classification of four groups of municipalities was the focus, because it offers a more detailed view of the socio-economic differences that exist between Slovenian municipalities and for that reason the results are more informative too. The variables that were used were socioeconomic development indicators. The K-Means algorithm is used to improve the results of Ward's method.

VI. Conclusions

This work uses the K-means algorithm to form a classification model for municipal management of local governments in Peru based on their indicators. The results have been presented in four groups, which shows a more detailed and informative picture of municipal management. The factors considered are related to human resources, heavy machinery and operational vehicles, information and communication technologies, municipal planning, municipal finances, local economic development, social services, solid waste management, cultural, recreational and sports facilities, public security, disaster risk management and environmental protection and conservation factor.

Cluster 1, formed by the municipal governments of Amazonas, Apurímac, Huancavelica, Huánuco, Ica, Lambayeque, Loreto and San Martin. Cluster 2 by municipal governments of Ancash and Cusco. Cluster 3 the municipal governments of the constitutional province of Callao, Madre de Dios, Moquegua, Pasco, Tacna, Tumbes and Ucayali. Cluster 4 the municipal governments of Arequipa, Ayacucho, Cajamarca, Junín, La Libertad, Region Lima, Piura and Puno. According to the results, it can be seen that the municipal governments of the constitutional province of Callao, Madre de Dios, Moquegua, Pasco, Tacna, Tumbes and Ucayali show poor municipal management and; on the other hand, the municipal governments of the Ancash and Cusco with efficient municipal management.

The application of the K-means algorithm is a contribution to the municipalities, in order to improve the municipal management by making right decisions for the benefit of their inhabitants.

VII. Future Work

Research efforts in this work, have been focused on some specific questions, the application of K-means algorithms in the management of municipalities; the analysis of municipal management by regions has been reserved for future work.

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Dynamic SEIZ in Online Social Networks: Epidemiological Modeling of Untrue Information

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***Abstract*—The epidemic propagation of untrue information in online social networks leads to potential damage to society. This phenomenon has attracted attention to researchers on a faster spread of false information. Epidemic models such as SI, SIS, SIR, developed to study the infection spread on social media. This paper uses SEIZ, an enhanced epidemic model classifies the overall population in four classes (i.e. Susceptible, Exposed, Infected, Skeptic). It uses probabilities of transition from one state to another state to characterize misinformation from actual information. It suffers from two limitations i.e. the rate of change of population and state transition probabilities considered constant for the entire period of observation. In this paper, a dynamic SEIZ computes the rate of change of population at fixed intervals and the predictions based on the new rates periodically. Research findings on Twitter data have indicated that this model gives more accuracy by early indications of being untrue information.**

***Keywords*—Information diffusion; epidemic models; SEIZ; rumor detection**

I. INTRODUCTION

The term “Social Networks” (SNs) was first coined Barnes in 1954[1]. It emerged in the form of e-mail and now used in many applications. In the last few years, SNs also referred to as social media have spread at a phenomenal pace covering people in every walk of human society. It has allowed people to share ideas, opinions, and seek information quickly and effectively. Emergence and boom of social networking websites like Facebook, Twitter and Reddit have proved useful in catastrophe control required in situations like flood, storm, and earthquake. These platforms have been equally effective in mitigating situations caused due to terrorist attacks, shootouts, and other similar situations. All these platforms are open platforms on which people can share whatever they wish with almost no censorship or filtering or verification of the contents by the media operators.

The enormous use of online social networks (OSNs) by millions of daily active users leads to radical changes in information sharing and communication among users as in [2]. Statistics show that over the years 2016-2018, about 20% of adults received news from U.S. social media websites [3]. According to study results [4], in 2017, the news on selected countries named Television as their source of news with 41 %, while 44% identified the internet.

(Including social media) as their source of news, as per in Fig. 1.

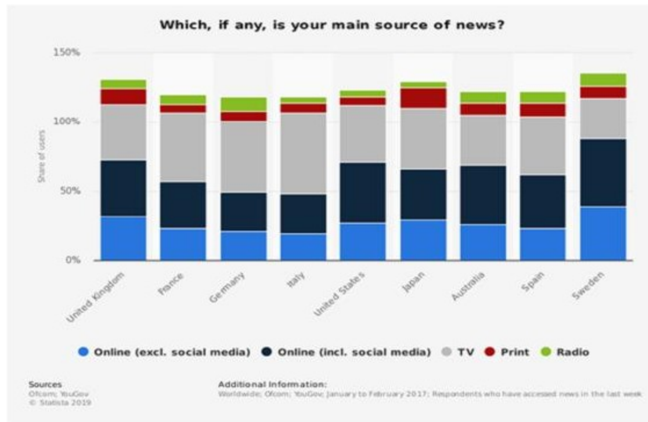

Fig. 1. Selected Country News Sources (2017) [5].

Websites intentionally publish hoaxes, rumors and misleading information popping up all over the web, and are shared on social media to extend their reach [5]. Terms such as "false news", "post-truth" and alternative facts" that is strongly associated with exposure of news in media. For example, stories such as Hillary Clinton's commercialism weapons to ISIS and Pope Francis support Trump for President liked and commented thousands of times on Facebook. Also, 14% of the people admitted that they have deliberately shared a fake political news story [6]. It is clear from this that the false news will continue to gain attention as long as users are still willing to share online. Even the current online checking system, such as Factcheck.org and Politifact.com, are standard detection approaches supported by professionals who specialize in the verification of the story item. Besides, every day a large amount of real-time information posted, answered, replied and shared via online social networks, which makes the detection of false news even harder.

In recent years, extensive research carried out on the establishment of an automatic and effective system or framework for the detection of online fake news and thus retrieving the useful and valuable information. Identifying legitimate information from a large amount of data available at different platforms is a challenging task because of the heterogeneous and dynamic nature of online social communications.

Misinformation can be defined as any malicious information that has spread deliberately or unintentionally (i.e.

without realizing it is untrue) [7]. Dissemination of false information has currently become identical with fake news. Moreover, the longer misleading information spreads within the network of a trusted source, the greater the impact. However, it is desirable to avoid unnecessary propagation of messages that causes an excessive burden on infrastructure that is used as long as-over emergencies [8].

The problem of false information or rumors in online social networks usually observed as misinformation or rumor blocking [9]. In addition, the lowest set of users can minimize the effect of spreading achieved by the originators of rumor. Other rumors distinguished by the subset of users act as the defender against the dissemination of misleading information sources [7]. The goal was to find the smallest subset of influential users and restrict the spread of misinformation to the specified ratio in a given set of the population. The proliferation of competitive campaigns evolving and aiming towards the selection of the appropriate subset of nodes such as the influence of misinformation campaigns also decreased as in [10].

For the effective and efficient solution to the problem, a series of research questions that need to address-

- How to effectively eradicate misinformation and understand the news propagation ways
- How contradictory information affects an individual's decision to accept and share the contents
- How can misinformation sources are early identified
- How to visualize and classify the misinformation of high dimensional real-time data

A. Research Challenges and Issues

The research challenges from the motivation of various papers on online fake news detection and some missing research directions are as follows:

- Determining an effective and reliable detection system for the analysis of rumor content in OSN's as early as possible.
- The studies suggest that online detection of fake content diversified in terms of methodologies, objectives, and research areas. Summarization of varied techniques and methods, with representative features, and evaluation of existing detection systems is required.
- The binary classification is not sufficient to classify the characteristics of deceptive information because of the complexity of the detection of untrue information. Data visualization is a powerful tool to illustrate the heterogeneity of social structures and the dissemination of social information online modes.
- In addition to the detection system, two aspects of promising research aimed at combating the false news. They are: (a) the early prediction of false news (i.e. it is very significant to identify trends or potential false news as early as possible.); and (b) False news intervention (i.e. from the historical data, the initial predictions appear false news or rumors before the intervention). This work tries to assess whether the system is based on online communication information is news or rumor. However, it is extremely significant to identify trends or potential false news as early as possible.

B. Contributions

The contribution of the work summarized as follows:

- The SEIZ epidemic model used to simulate the Twitter dataset in real-time. The non-linear least square optimization used over tweet data to underlying network ODEs and demonstrates how false information modeled with the SEIZ.
- Comparison and data analysis between classical and dynamic SEIZ in the network provides an early indication and distinguishes the rate of change of population with time on Twitter data, respectively.
- The parameters–Exposed Ratio (RSI) and Reproductive Number (R0IZ) that show the capability of the SEIZ model to quantify information to be a rumor in compartment transition dynamics. In addition, these measures provide suggestive results for the rate-infected user affects the exposed compartment and susceptible compartments.

The paper structure is as follows; Section 2 presents a comprehensive description of existing work in epidemic models and rumor models. Next, Section 3 demonstrates a detailed analysis of SEIZ with experimental evaluation by fitting it with the dataset. Section 4 provides a comparative study with a classical and modified dynamic SEIZ model with results. It also determines early rumor detection ratios for identifying them in the network. Finally, Section 5 concludes the research study.

II. Related Work

A significant amount of work studied and modeled into research on information diffusion in social networks, which includes epidemic models and rumor modeling techniques in literature with their significance. Below is the summarization of these techniques from the literature.

A. Epidemic Models

Diffusion of information similar to the spread of the epidemic, but there are differences. Information diffusion is related to time, the strength of the relationship, information content, social factors, network structure, etc. Researchers have made ongoing improvements based on the classical model, developing new models such SI model (i.e. Susceptible, Infected) by [11], SIS model (i.e. Susceptible, Infected, Susceptible) by [12], SIR model (i.e. Susceptible, Infected, Recovered) by [13], SIRS model (i.e. Susceptible, Infected, recovered, Susceptible) by [14]. The SEIZ model (i.e. Susceptible, Exposed, Infected, and Skeptic) proposed by [15] takes a distinct approach by introducing a state Exposed(E). It is quite an effective mapping disease model with rumor models [16]. Several papers study the properties of spreading information online social networks with emphasis on Twitter [17][18](Wang et al., 2013).

Information diffusion includes a set of characteristics summarized as follows: Diffusion minimization problem which identifies a small set of individuals with whom the dissemination of information diffusion is higher [19][14]. The role of users before the spread and classifying them consistent with their activity (i.e. re-tweeting, generating new tweets, commenting tweets, mentioning, replying, no. of followers so on) [13][15][17]. The re-tweet chain and the range of information diffusion [17], Hash-tags[20], temporal and topical patterns [21]. Modeling and studying the dynamics of information diffusion through the model of temporal dynamics of the epidemic and the diffusion of information on Twitter by [22].

The SEIR model was developed by adding another compartment Exposed (E) nodes supported the SIR model [23]. It is a dynamic information propagation method to analyze the impact of the frequency of the logged-in user and various friends. The results showed that the frequency of the logged-in user is directly proportional to the speed and range of transmission of information. S-SEIR model designed for single-layer social networks that support SEIR and its transmission of information depends on user activities [24]. SCIR model assumes that all followers assigned to the contact state 'C' when the user posts a message. It is a model for Micro-blogs by adding a contacted state (C) and provides an online topic spreading model [23][24]. In addition, the state of the followers may change according to a certain probability, the change in transmission or immune users after a particular duration. In [25], proposed model IR-SIR based on the SIR model simulating the adoption and abandonment of user views by adding a recovery process of the mechanics of the infection and verified the process on Facebook and Google. In [26], proposed the FSIR model that considers the effect of neighbors on an individual within the diffusion information. The threshold for spreading of information is zero and affects information diffusion. ESIS model based on SIS by [27], where the information transmitted between people has expressed a sort of emotional information.

Compartmental models are a mathematical approach applied to measure and predict the spread of various infectious diseases. The method of misinformation diffusion is usually a similar approach as a virus spreading process. In transmission epidemics, there is each user infected with viruses and can become susceptible to viruses. In [15], proposed the SEIZ model where the skeptics are the individuals becoming immune to infection. Although it is similar to the removed (R) individuals, skeptic transitions directly from the susceptible state and their interaction will still affect different compartments as well.

B. Rumor Modeling

In 1964, analogy between the spreading of infectious disease transition and information propagation in the network was given [28]. In particular, it emphasizes on a mathematical model for the spreading of infection in several ways, depending on a mechanism to describe the growth and decay process. Later experimentation conducted that guaranteed greedy approximate solution applied to Facebook [10]. According to the results, minimizing the spread of misinformation in social networks (SNs) is an NP-hard problem. Similarly, rumors detection problems in the micro-blog explore the effectiveness of into three categories (i.e. content-based, network-based, and micro-blog memes) for correctly identifying rumors [14]. [29]analyzed information credibility of news propagated through Twitter. The results are evidence that there are measurable differences in the way messages propagate, with a range of 70% to 80% of precision and accuracy rates. [30] Modeled rumor propagation in the network with the model Susceptible- Infected (SI) and constructed an estimator for the rumor source. They established a maximum likelihood (ML) estimator for a graphic class to find rumor sources in the network. The stochastic epidemic study on infection spread and rumors on networks, focusing on the SIR epidemic by ignoring density correlation between neighboring nodes investigated by [31]. This method computed mathematically and compared with the mean-field deterministic model over the set of equations.

C. SEIZ Model

Compartmental models are a mathematical approach used to evaluate and predict the spread of various infectious diseases [35]. SEIZ model is a compartmental model that breaks the population into distinct compartments and establishing parameters for the rates at which the population transitions between compartments. These parameters obtained by looking at the relationships between each class of the population and making assumptions about the disease. With this, a set of differential equations generated to make predictions about the spread of the disease. A basic approach that is more practical than the SI model. Here the population divided into three compartments: Susceptible (*S*), who are the individuals at risk to the disease; Infected (*I*) which are those who have the disease and are capable of transmitting it. Removed I which are individuals who can no longer be infected or infect anyone else, so they either died from the disease or they have recovered and are now immune [32]. A great application of this model would be to a disease like measles, where once recovered, an individual has immunity for life. One of the assumptions made in this Susceptible-Infected-Removed, or SIR, model, is that the overall population, *N*, and is constant.

$$\frac{dN}{dt} = 0, \quad (1)$$

$$N = S + I + R. \quad (2)$$

Suppose that individuals only transition from S to I at a contact rate of $r > 0$ and from I to R at a transition rate of $a > 0$, as shown in Fig. 2.

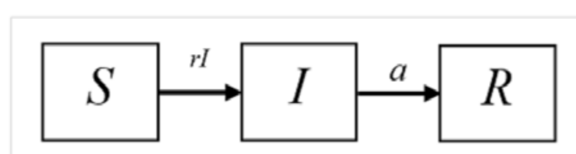

Fig. 2. Transition Rates of SIR Model.

These relationships then used to generate a system of ODEs:

$$\frac{dS}{dt} = -rS\left(\frac{I}{N}\right) \tag{3}$$

$$\frac{dI}{dt} = rS\left(\frac{I}{N}\right) - aI \tag{4}$$

$$\frac{dR}{dt} = aI \tag{5}$$

The rate at which the individual SI transition depends on r as well as the number of individuals infected. The rate of change depends on Infected (I) because if someone is in contact with an infected individual and becomes infected. The transition rate from I to R, however, is only dependent on ‘a’ as per the equations 3, 4 and 5. The transition for each individual out of the infected compartment is independent of everyone else for this model. Another simple model used is the Susceptible-Infected-Susceptible, or SIS, model as shown in Fig. 3.

In this case, it has assumed that instead of dying or becoming immune, the infected individual transition back into the susceptible class. Thus, this model used for diseases such as gonorrhea, because individual does not gain immunity after recovering from an infection. Though this model is not perfect, its simplicity can give us a good idea of what is going on. If we assume that individuals transition from S to I with a contact rate of $r > 0$and back from I to S with a transition rate of $\lambda > 0$, gives.

With these relationships, the following system of ODEs generated:

$$\frac{dS}{dt} = -rS\left(\frac{I}{N}\right) + \lambda I \tag{6}$$

$$\frac{dI}{dt} = rS\left(\frac{I}{N}\right) - \lambda I \tag{7}$$

According to the SIR model, the rate of transition from (I) is independent of anything except the parameter ‘λ’. In addition, the rate of transition from S to I depends on the parameter ‘r’, and the number of people in the infected compartment as per the equation 6 and 7.

One major drawback of SIS and SIR models is that a susceptible individual moves to the infected class immediately after exposure to an infected individual. This is usually not the case; however, as many pathogens take time to develop during a phase of incubation. For these instances, an Exposed Compartment (E) incorporated to indicate those who have met an infected individual, but it takes some time in the model to infect them themselves. From this extension, the SEIZ model explored one more compartment Skeptics (Z). Z recruit from the susceptible population with rate ‘b’, but results either in transforming the individual into another skeptic (Z) with probability (l), or can have unintended effect of sending that individual to the incubator class with probability (1-l).

In this model, the susceptibility immediately infected with probability ‘p’, and ‘(1-p)’ is the possibility of an individual transiting to the incubator class instead, from which they adopted. ‘N(t)’ denotes the total population where the network has a disease-free status with S*=N, E*=I*=Z*=0. Fig. 4 illustrates the relationship between each compartment.

Table I and Table II provide description of each parameter of this model. This provides a more intuitive look into the model and relates the relationships above with the actual equations:

With the relationships between each compartment described by the parameters above, we have the following set of ODEs:

$$\frac{ds}{dt} = -\beta * S\left(\frac{I}{N}\right) - b * S\left(\frac{Z}{N}\right) \tag{8}$$

$$\frac{dE}{dt} = (1\text{-p})\beta S\left(\frac{1}{N}\right) + (1-l)bS\left(\frac{Z}{N}\right) - \rho E\left(\frac{1}{N}\right) - \varepsilon E \tag{9}$$

$$\frac{dI}{dt} = p\beta S\left(\frac{I}{N}\right) + \rho E\left(\frac{I}{N}\right) + \varepsilon E \tag{10}$$

$$\frac{dZ}{dt} = lbS\left(\frac{Z}{N}\right) \tag{11}$$

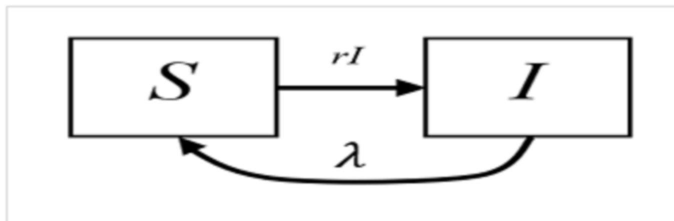

Fig. 3. Transition Rates of SIS Model.

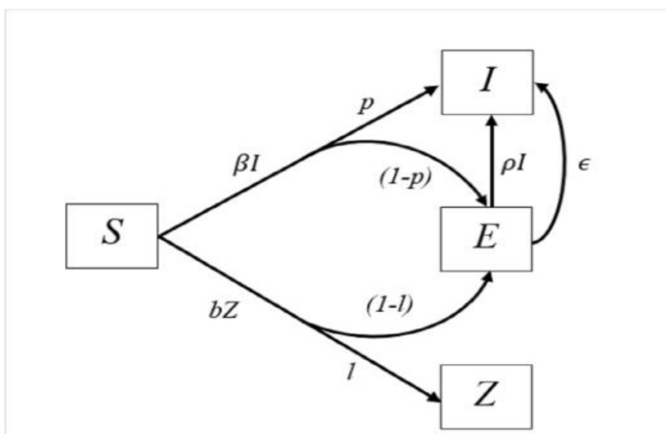

Fig. 4. Transition Rates of SEIZ Model.

TABLE I. NOMENCLATURE FOR STATE TRANSITION VARIABLES OF SEIZ MODEL

Variable	Definition
Susceptible (S)	The onset of the spread of infection
Exposed (E)	Incubator class, in contact with infection
Infected (I)	Adopters class, incubate infection and eventually manifest it and becoming a member of adopter
Skeptic (Z)	susceptible are turned off from infection and become skeptic/stifler
Population(N)	Total population

TABLE II. DESCRIPTION OF PARAMETERS IN SEIZ MODEL

Parameter	Meaning	Units
β	Rate of contact between *S* and *I*	Per unit time
b	Rate of contact between S and Z	Per unit time
ρ	Rate of contact between E and I	Per unit time
p	Transmission rate S->I, given contact with I	Unit-less
(*1-p*)	Transmission rate S->E, given contact with I	Unit-less
l	Transmission rate S->Z, given contact with Z	Unit-less
(1-l)	Transmission rate S->E, given contact with Z	Unit-less
[illegible]	Transmission rate of E->I	Per unit time

In [16], studied the SEIZ and SIS models for the spread of news on Twitter and found the SEIZ model produced much better results. When the models were optimized against Twitter data from 4 news stories and 4 rumors, it was found that the SEIZ model consistently had a much lower relative error than the SIS model. SEIZ suffers from two limitations i.e. the rate of change of population in a state and state transition probabilities considered constant for entire period of observation. This requires the population to reach a certain level before making any trustworthy characterization of information as untrue information resulting in substantial delay in characterization of untrue information. Assuming static rate of population, estimates delayed accuracy of results. In this paper, a dynamic SEIZ computes the rate of change of population at fixed intervals and the predictions based on the new rates periodically. This approach provides the early indications of information being untrue.

III. MODEL FITTING

The scripts used for fitting the model and performed multi-linear regression to study Twitter data from actual data. The entire experimentation performed in Python 3, solving ODE equation with period 7 days of information spread by Higgs Boson. The computed response ratio for days, R_{SI} and relative error (*Err*) produced between infected tweets in time, *I(t)* and actual tweets. The inputs were taken from Higgs networks which are fitted in each of the compartments of *S, E, I, Z,* where Z to be skeptic population assumed to be 1 as the initial condition for prevailing days with time.

A. Dataset used

The Stanford Network Analysis Project (SNAP) used 14 million tweets [33]. With the discovery of a new particle, the Higgs dataset used to analyze the process of information-spread on Twitter. The messages posted on Twitter on this exploration between 1st and 7th July 2012 taken into consideration. Accessibility of the four directive networks derived from Twitter user behaviors is as follows:

1) Re-tweeting (retweet network)

2) Replying (reply network) to existing tweets

3) Mentioning (mention network) other users

4) Friends/followers social relationships among user involved in the above activities

5) Information about activity on Twitter during the discovery of Higgs boson

It is worth remarking that the user IDs has anonymised, and the same user ID used for all networks. This choice allows using the Higgs dataset in studies about large-scale interdependent/interconnected multiplex/multilayer networks, where one-layer accounts for the social structure and three layers encode different types of user dynamics.

B. Experimental Evaluation

Data on a particle discovery obtained from Twitter, applied the classic model, and modified model of SEIZ. Here the social network contains 456,631 nodes and 14,855,875 edges to fit and model in dynamic SEIZ. Further its accuracy evaluated for early detection of rumor content by R_{SI} and R_{0IZ} (i.e. standard parameters for rumor measure in the network).

In the context of Twitter, various compartment SEIZ interpreted as follows: susceptible (S) is a person who has not heard about the tweet, infected (I) indicates an individual who had tweeted about the tweet, skeptical (Z) are individuals who have learned of the tweet but chooses not to tweet it. In addition, the exposed (E) are those who receive tweets but it took some time before the posting. The inputs for the function are the initial conditions of each compartment(*S, E, I, Z*), and the total population as N = S+E+I+Z. Then solving the system of ODEs and computing the result. The initial conditions known of the dataset. Assuming that the skeptic Z (i.e. dormant accounts) to be 1% of total population. The goal of optimizing these parameters is to minimize equation. Some of the constraints to this minimization problem are that all of the parameters from Table III must be non-negative. Thus the parameters values β, b, ρ, $s \geq 0$ and $0 \leq p$, l ≤ 1. Similarly, the compartments must also be non-negative.

The parameters in Table III calculated from the SEIZ ODE solving previously mentioned in the equations (8-11). To demonstrate SEIZ mathematical model, quantities from Higgs Boson fitted in this model. Data implementation written in Python to extract data from each network from this large social network data set. Here classical SEIZ model computed and compared with the result of modified SEIZ model that provides early detection and indication of rumor in the network provided with information in time slots of 7 days. Experimentation performed for one day, three days, five days, seven days and data obtained for each day respectively.

TABLE III. PARAMETER ESTIMATIONS FOR THE SEIZ MODEL

Duration(Days)	*β*	*b*	*ρ*	*s*	p	l
1 Day	6. 1799	4.539E -05	2.1431 E-01	0. 1356	.9767 E-01	5.234 E-05
3 Days	.6 865	5.0281 E-05	.0238	.0 452	.3616	19.398 E-10
5 Days	2 471	1.8101 E-05	.0085	.0 271	.0781	4.1900 E-10
7 Days	1 260	1.9234 E-06	.0044	.0 198	.0284 3	1.526 E-12

Fig. 6 demonstrates that the susceptible (*S*), Exposed (*E*), Infected (*I*), Skeptic (*Z*) individuals began to increase with the time (i.e. retweet/reply/mention in the network during the 7 days). For 1 day, *E(t)* and *S(t)* decreases at the rate negative to that of *I(t)* increase. In fact, *I(t)* coincides with *S(t)* with number of days making more exposed population in E(t) compartment. For other days, it is observed that *S(t)*, *I(t)* and *E(t)* becomes constant over certain period in the network. Thus, there is no significant amount of changes seen for 3 days, 5 days and 7 days with static classical SEIZ approach. The remaining cases of SEIZ plots are shown in Fig. 5 with S, E, I, Z dynamically changing over time.

The time varying network for all four compartments in Higgs Twitter's SEIZ time course plots in Fig. 6 suggest that the effective rate of skeptic population becoming susceptible is much higher than the infected population for 1 day. With an increase in *Z (t)*, *S (t)* decreases and thereafter, *S (t)* is stable together with *Z (t)*. *I (t)* increase as *S (t)* decreases, but its rate of change is slower. There is also a strong correlation between E (t) and I (t) increases. As *I (t)* peak, *E (t)* peaks as well. However, the increase of E (t) closely correlated with the decrease compartment S (t). Most of the increase I (t) occurs after S (t) has developed minimum values, which demonstrates that the infected compartment is constantly changing.

Obtained results from data shows early indication of untrue spread of information/particle spreads which states that dynamic SEIZ works well when obtained in dynamic time intervals over a large network. It also clearly distinguishes data from classical model by stating its rate of change in the entire four networks to be faster with time irrespective of early distinguishing the true and untrue information.

C. Comparison with Classical and Dynamic SEIZ

The modified SEIZ provides early indication of untrue information in the network with increase in number of days in the network. For 5 days to 7 days we can observe significant peak rise with modified technique which suggest that increase in infected users is because of transition of large amount of users from infected to exposed compartment over time (*t*) in the network. Comparing both techniques in Fig. 7.

The infected compartment increases rapidly from the exposed population and not from the direct recruitment of susceptible individuals. Thus, these findings suggest that the generation of early indication of propagation of misinformation spread in the Higgs Boson network.

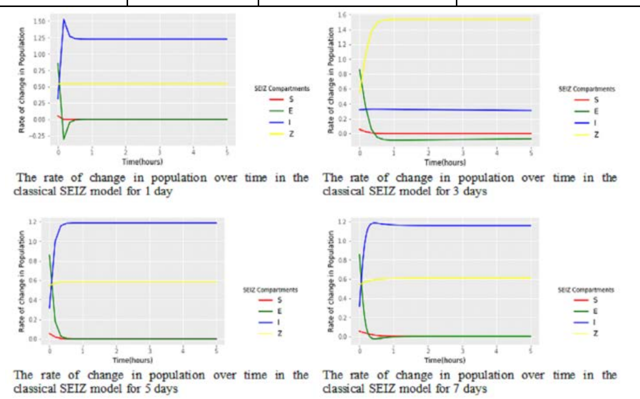

Fig. 5. Rate of Change in Population Over Time for Classical SEIZ Model.

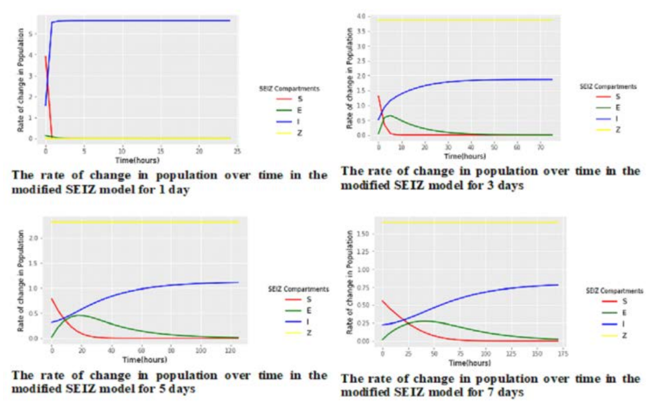

Fig. 6. Rate of Change in Population Over Time in Modified SEIZ Model.

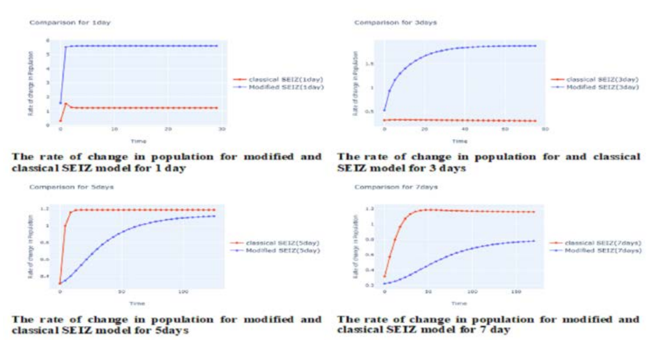

Fig. 7. Comparison between Modified and Classical SEIZ Model Over Time.

IV. Rumor Detection

Next requires determining the Exposed Ratio (R_{SI}) and the Reproductive Number (R_{IZ}) to recognizing the quantity of untrue information on Twitter data. Analysis of this fixed point's local stability shows that the specific reproductive numbers are given by equation 10 where,

$$R_0^{IZ} = \left(\frac{\beta(\varepsilon + p\mu}{\mu(\varepsilon + p\mu)} \right) \tag{12}$$

R_0^I corresponds to an eigenvector with the adopter component. R_0^{IZ} corresponds to the exclusive rise of the skeptical population without recognizing the infection. R_0^{IZ} is the criterion for adopters invaded in a susceptible population. If R_0^{IZ} >1 it will spread the infection. The higher R_0^{IZ}, more successful is the acceptance ratio of the infection. By assembling equations to relate the primary parameters of the SEIZ model, R_{SI} is the ratio of the number of effective transition rates that arrive (from *S*) to the sum of transition levels that exit the compartment (to *I*). R_{SI} holds all of the SEIZ model's rate constants and probability values and relates them to the exposed flux-ratio i.e. the ratio of effects entering *E* to those leaving *E*. The ratio, called the Exposed ratio, given by equation 11:

$$R_{SI} = \frac{(1-p)\beta + (1-l)b}{\rho + \varepsilon} \tag{13}$$

The Exposed ratio may be able to indicate a difference between news stories and rumors. A value greater than 1 for RSI means that the transition rates from S to E were greater than from E to I. If the ratio is less than 1, than the exit rates are greater than the entry rates. For the cases studied in [16], it was shown that the news stories typically had RSI > 1and the rumors had RSI < 1. Similar computation followed on dataset with these values indicating early signs of rumor/infection in the network. Table 4 illustrates RSI and RIZ the values for the modified SEIZ model.

The values of RSI in the Fig. 8 shows that for the very first day when SEIZ applied, the exposed population from Susceptible to Infection compartment detects with -15.95 rate of influx to efflux. This shows that modified dynamic SEIZ results in early prediction of rumor count, which initially detected for 1 day. For the rest of days this ratio positively shows with 5 to 6.39 which potentially giving non-rumor rate of diffusion.

R_0^{IZ} corresponds to an eigenvector with the adopter component gives exclusive rise of the skeptical population without recognizing the infection. R_0^{IZ} is the criterion for adopters invaded in a susceptible population. If R_0^{IZ} >1 it will spread the infection. The higher R^{IZ}, more successful is the acceptance ratio of the infection. By assembling equations to relate the primary parameters of the SEIZ model, R_{SI} is the ratio of the number of effective transition rates that arrive (from *S*) to the sum of transition levels that exit the compartment (to *I*). R_{SI} holds all of the SEIZ model's rate constants and probability values and relates them to the exposed flux-ratio i.e. the ratio of effects entering *E* to those leaving *E*. The ratio, called the Exposed ratio, given by equation 13.

Thus, R_{SI} determines that the greater R_{SI} value more susceptible enter in exposed group and with the time this ratio decreases which gives us there can be situation that all exposed population can prone to untrue information with time information diffused in the network. For 1 day to 7 days provides a clearer indication of *I (t)* infected population creating rumor.

The R^{IZ} value estimates the average number of adopters induced by a standard spreader in a susceptible population as shown in Fig. 9. These tests the infection's effectiveness as R^{IZ} > 1, the infection spreads in a network. The greater the R^{IZ}, the greater is the potency of the infection Fig. 10 determines the similar result that infection rate is much higher for the first day with 122.57 which gradually decreases with *I(t)* becoming *Z(t)* skeptic. Larger the values of R^{IZ} estimated in the SEIZ model are mainly due to the very long lifeline of the infection *I (t)*. In practice, R^{IZ} can be estimated by linearizing *I(t)* around disease-free equilibrium in simple models [36]. In Fig. 11, R^{IZ}s provides a statistical distribution to match Feynman diagram spread data [34].

TABLE IV. Rumor Detection Ratio Calculated for RSI and RIZ

Time(Days)	*RSI*	*RIZ*
1day	-15.95	122.57
3days	6.35	43
5days	6.39	34
7days	5.05	25

Fig. 8. $R_{SI\ value}$ for SEIZ.

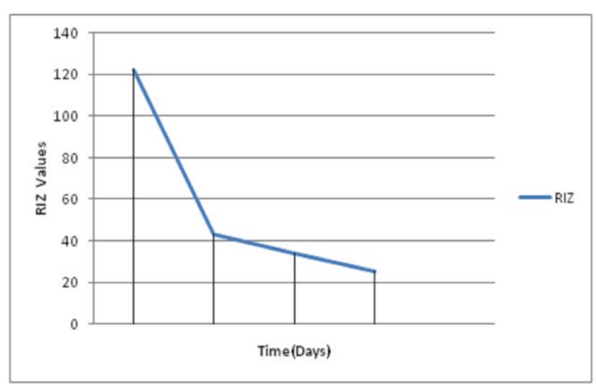

Fig. 9. R_{IZ} value for SEIZ.

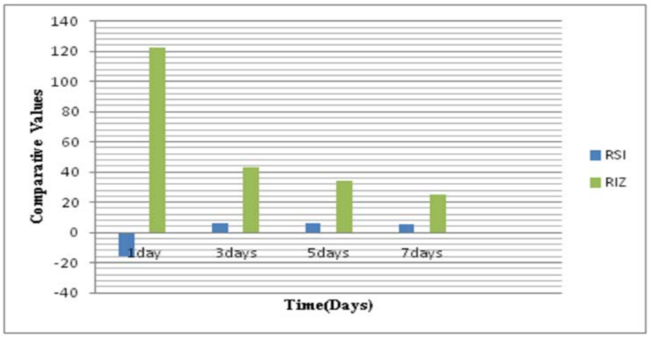

Fig. 10. Comparative value for Rumor Detection.

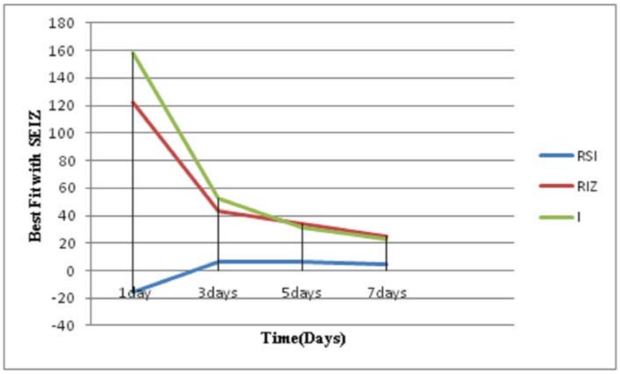

Fig. 11. Best fit in Modified SEIZ.

V. Conclusions

Early prediction can remind users of all potential risks with false information before it exists. The false news intervention can eradicate users to erase the negative impacts of false news. In this paper, a model inspired SEIZ epidemiological applied to the population to detect false information dissemination. SEIZ model is capable of modeling the false content of large sets of network with earliest possibility in dynamic network. Exposed ratio (R_{SI}) and Reproductive Number (R^{IZ}) is a unique value and too sensitive to change in parameter values used to gain useful information from it. Specifically, on Twitter, this paper demonstrates how these criteria incorporated into the strategy to support the early detection of Twitter infection. The findings suggest that Twitter data provides valuable dissemination information with other data analysis strategies to provide accurate and reliable results.

VI. Future Work

By examining, more data sets in the future further will strengthen the claim made that SEIZ model is a great model for early prediction of untrue information propagation on Twitter. In addition, these epidemiological models with reinforcement learning can mitigate the effect of false news on social media. Removing suspicious accounts online, protecting users with false information and some automated methods aids in reducing the spread of false news online. Thus has a potential research direction for big data systems.

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An Artificial Intelligent based System to Automate Decision Making in Assembly Solution Design

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***Abstract*—Nowadays, competitiveness between industries has become very strong. Thus, industries are faced to serious challenges in terms of products qualities, time development and production cost. As assembly operations difficulties cause a big part of production problems, the integration of assembly selection since the earlier product life cycle phases has become a necessity for every company in order to survive. However, despite the large number of approaches that have been proposed in order to achieve this integration goal, many other problems are still present. It is in this context that a flexible and automated decision making system is proposed. It is based on ontologies and also on the Case Based Reasoning (CBR) and Rule Based Reasoning (RBR) concepts. Indeed, this system is an automation of the integrated DFMMA approach, in particular its assembly solution selection methodology. The developed system permits to designers avoiding the redundancy in the works by benefiting from their previous studies and their experience. In addition to that, it facilitates and automates the assembly solution selection even if the number of assembly alternatives is high. Finally, to illustrate the efficacy of the proposed system, a case of study is developed in the end of the work.**

Keywords*—Assembly selection; product assembly; ontologies; CBR & RBR; flexible and automated; decision making system; artificial intelligence

I. Introduction

Nowadays, competitiveness between companies and their industrial products has become very strong. Actually, costumer's requirements, development speed of the world and its continuous changes face industries to high levels of challenges in order to survive in the market and to keep in their places. Thus, industrial companies have to be quick and efficient in the same time in the development and the production of their products.

As assembly operations occupy a very important place in this context and their success without difficulties help in a high percentage to the achievement of any industrial company goals, this production phase has to be taken into consideration since the earlier stages of product life cycle, namely in the design phase. It is in this context that the DFA (Design For Assembly) concept and many other adjacent concepts have appeared. However, the majority of their approaches present two main limits. Firstly, they are theoric and manual, thus in case of having a high number of assembly alternatives, the selection becomes impossible. Secondly, the experience of designers is not taken into consideration which produces a redundancy in the work. Consequently, a lack of selection quality and also a waste of time and money are present.

To overcome all those limits, an automation of the optimal assembly solution selection becomes an obligation.

Thus, in this paper, a flexible and automated assembly decision making system based on ontologies is developed.

Indeed, through the high capacities and the different potentialities of this emergent artificial intelligent tool, the selection of the optimal assembly solution since the product design phase could be done in an efficient and automated way. In addition to that, in order to achieve the same goal, the proposed automated system is based on two main types of reasoning which are: the CBR (Case Based Reasoning) and the RBR (Rules Based Reasoning).

The approach, that was chosen to be automated, is the assembly solution selection methodology of the DFMMA (Design For Materials, Manufacturing and Assembly) approach. This choice is done because of the different advantages that present this integrated design approach. All its details are presented in our previous work, Reference [1] but the implementation of the approach was not automated. Thus, this work is an automation of the assembly selection part of our DFMMA approach.

It is to note that the proposed ontology is named ADM-Onto referring to Assembly Decision Making Ontology. With regards to the proposed system, it calls ADM system which refers to Assembly Decision Making system.

Thus, in the next section, a literature review about the different DFA approaches, about the assembly methodology presented by the DFMMA approach and its advantages and also about ontologies is presented. In the third section of this paper, the ADM system is described. The ADM-Onto is constructed in the fourth section. Section five and six are dedicated to the description of the working process of the CBR and the RBR modules of the automated ADM system. Finally, to illustrate the efficient results of the ADM Methodology (Assembly Decision Making Methodology) a case of study is developed at the end of the work.

II. Literature Review

The first phase of any product life cycle is the design. It plays a key role in the optimization of the product quality, its production time and its cost later.

According to the systematic approach proposed by Pahl and Beitz [2], this phase is composed of four main stages which are: Product planning and clarifying the task, Conceptual design, Embodiment design and Detail design.

Each one of those stages aims to have a set of specific objectives that contributes to the achievement of the next stage.

Having regard to the detail design phase, one of its main goals is to select the optimal assembly solution for the studied product. It is in this context that Design For Assembly (DFA) has appeared and many approaches have been proposed to support the assembly phase from the earlier phases of product life cycle.

One of the most famous proposed approaches is the Hitachi method, called also AREM (Assembly Reliability Evaluation Method) [3]. It aims to determine the different kinds of faults that can take place during the assembly phase of a complex product. It is based on two indicators: an assemblability evaluation score ratio (E) that estimates design quality from the difficulty of operations and an assembly cost ratio (K).

Another DFA approach is the Lucas method [4] that bases its optimal assembly solution selection on three indexes related to three separated and sequential analyses: the functional analysis, the feeding analysis and the fitting analysis.

Moreover, Boothroyd and Dewhurst have also proposed a practical method [5] that has as an objective the comparison between different assembly alternatives basing on their manual assembly rate. This rate is defined from an efficiency indicator (E_m) that can be calculated using the following formula:

$$E_m = \frac{T_m}{T_a} = \frac{N_m \times 3}{T_a} \quad (1)$$

With:

- Tm: the ideal time for assembly,
- Ta: the real time to make the operation
- Nm: the ideal number of product parts

In this index (E_m) formula, the ideal time is correlated to the ideal number of parts by considering 3 seconds for their assembly.

In the same context of DFA, Samy and ElMaraghy have developed a methodology based on the product assembly complexity as an index to optimize the assembly solution selections [6,7].

In contrast to all those traditional works that base their assembly solution choice on different indexes, many new researches have treated the DFA using other different ways. Actually, Stone and McAdams have proposed a DFA approach based on the functional basis concept and the method of module heuristics [8]. Furthermore, Favi and Germani have developed a flows analysis based DFA method [9]. In another work, Favi et al. have taken into account several aspects such as assemblability, manufacturability and costs in order to perform the selection of the best product modules configuration [10].

In addition to the DFA concept, many other concepts have appeared to support assembly problems from the earlier stages of product life cycle (in the design phase) namely, the DFMA (Design For Manufacturing and Assembly) concept and the integrated approaches of design [11].

One of the new relevant approaches, that have been developed, is the integrated DFMMA approach [1]. It is based on the systematic approach of design and integrates in the same time the most important pillars of product life cycle, which are: design requirements, materials characteristics, manufacturing parameters and the assembly process specifications. It is based also on different quantitative indexes and tools without neglecting the subjective side of design optimization problem.

In regards to the selection of the optimal assembly solution methodology that proposes the DFMMA approach, a quantitative analysis strategy is developed and the decision is based on three indicators which are related to the three basic notions of any product lifecycle: the product quality, the product lifecycle time and the product cost.

Actually, by calculating a quality indicator, a time indicator and a cost indicator, a global assembly index can be calculated. The optimal solution is the one that has the highest value of this global indicator.

Table I presents the different proposed formula of those indicators [1].

Despite the advantages of each of those works, they present two main common limits. Firstly, any one of those proposed approaches takes into account the experience of the design team. Actually, designers do not benefit from their previous design studies, in particular, the optimal assembly selection of the ancient studied products. In addition to that, all those approaches are theoretical and manual. Thus, if the design problem is composed of a high number of assembly alternatives, the comparison between them becomes difficult and sometimes impossible. Then, those two limits present a serious problem in terms of quality decision-making and a big waste of time and money.

To overcome those problems, a flexible and automated assembly decision making system is proposed in this paper. It aims to automate the selection of the optimal assembly solution and to permit to designers the use of their ancient studies with an automatic way. To do so, an emergent artificial intelligent tool is used, namely, inference ontologies.

Indeed, an ontology is an explicit and formal specification of the concepts, individuals and relationships which exist in some area of interest. It is built by defining axioms that describe the properties of these entities [12, 13].

TABLE I. SUMMARY OF ASSEMBLY SOLUTION SELECTION INDICATORS PROPOSED IN THE DFMMA APPROACH [1]

Indicator	**Formula**	**Notation**
The Quality Indicator	$I_Q = \frac{N_{sp.ver}}{N_{sp.tot}}$	Nsp.ver: number of specifications which are verified by the assembly alternative. Nsp.tot: total number of the imposed specifications
The Time Indicator	$I_T = \frac{f_{fa} \times f_{am} \times f_{ir} \times T_{id}}{T_{re}}$	f_{fa} : Fatigue factor f_{am} : Ambient factor f_{ir}:Irregularity coefficient T_{id}: ideal/ theoretical time to assembly the studied product T_{re}: real time to assembly entirely the studied product
The Cost Indicator	$IC = 1- \frac{C_{AT}}{C_{av.pro}}$	C_{AT}: total assembly cost of the alternative $C_{av.pro}$: total average cost of production of the studied product
The Global Assembly Indicator	$IG = IQ \times IT \times IC$	-------

Ontologies have different capacities [14]. The first one is their integration and completeness, assured by language expressivity [15]. In addition to that, they are characterized by an embedded intelligence, due to their reasoning capabilities [16, 17]. Finally, they offer a dynamism and flexibility abilities through queries and web services.

Thanks to all those cited potentialities, Ontologies are used in different domains, namely: the supply chain management [18 - 20], the Product Lifecycle Management [20, 21], the collaborative Product Development and Simultaneous engineering [22]. Actually, in the context of industrial product design phase, many works have been developed as examples:

- The proposed Product Design ontology (PDO) [20]: It supports collaboration between designers
- The Ontology Decision Support ontology (DSO) [23]: It supports decision making in the collaborative design of the product
- The ontology-based model [24]: It provides understanding and semantic interoperability between the different partners in the context of collaborative products development and it ensures the capitalization of the previous projects knowledge
- The developed ontology of Bock et al. [25]: It consists on representing the different possible designs for a same product in order to have an agreement between the various partners on the architecture of the product from the early phases of its life cycle.
- The ontology proposed by Mostefai et al. [26]: It represents three basic points of view in Collaborative Product Development which are the design of the components, the assembly and the production plan.
- The developed ontology of Lee et al. [27]: It is a meta-ontology for products' design. It is based on five root concepts: Attribute, behavior, entity, property and object relationship.
- The ontology proposed by Kim et al. [28]: It supports the collaborative design of products
- The proposed ontology of Chang et al. [29]: It supports data integration and decision making during the collaborative design of products.

All those works have used ontologies either to represent product information or to represent its development process data. Some of them have combined the two in a clear and generic way [30]. In addition to that, those previous researches have not exploited the reasoning capacity of ontologies which offers the ability to infer new information.

Thus, in this paper, the proposed decision making system focus on the overcoming of this limit. Indeed, unlike many of the existing works, it uses this fundamental capacity, namely, the reasoning ability, that ontologies offer in order to make the optimal assembly solution selection of complex mechanical products easy and automated.

III. THE GLOBAL PROPOSED ADM METHODOLOGY

The goal of this paper is to automate the assembly selection phase. To do so, a structured methodology is proposed. It is based on ontologies, Case Based Reasoning (CBR) and Rule Based Reasoning (RBR) tools and methods. In fact, the combination of those three tools gives birth to a flexible and automated assembly decision making (ADM) system. In addition to that, the proposed methodology is based on the integrated DFMMA approach [1]. The choice of this approach was not random, but because of its different advantages, notably, the use of different quantitative indexes and tools throughout the study without eliminating the subjective side of design optimization problem.

Fig. 1 shows the global structure of the ADM system. According to the DFMMA approach, after the embodiment design that gives the design team its global architecture as a result, the studied mechanical product is divided into a set of modules which are assembled between them across different interfaces [1]. This step is done in the context of detail design phase. The second step of this phase is the materials and manufacturing processes selections. After this, the assembly solution selection should be done using the results of the previous steps as inputs.

As it is shown in Fig. 1, the proposed structured ADM system is decomposed to seven modules:

- The Information Collection Module (MCM): It is the first module in the proposed system. In fact, assembly selection step cannot be done correctly without sufficient information about the studied mechanical product. All of that information are the outputs of the previous steps of the design process.

- The Assembly ontology and the semantic model creator: Through the different characteristics and capacities of ontologies in expressiveness and storage, all the information collected in the previous module are expressed in a uniform language and capitalized in a same data base, which facilitates their use in the next stages. In addition to that, through this artificial intelligence tool, they are translated to a semantic model which will be the base of the subsequent decision-making.
- The Pre-Judging Module (PJM): This module permits to the design team the classification of the mechanical product in terms of components number. Actually, if the studied mechanical product is composed of one single element, it doesn't need to be assembled. In this case, the process of the proposed methodology is stopped. Otherwise, the process continues and the CBR/RBR processes are applied.
- The Case Based Reasoning Module (CBR module): This module allows the use of the previous assembly selection studies stored in the assembly ontology (the ADM-Onto) of the design team. In fact, the constructed assembly ontology contains a case base of the ancient mechanical products design. Thus, the design team uses their ancient studies and benefits from its experience to select the optimal assembly solution of its studied case. Actually, the studied mechanical product is adapted to a similar one, either by adopting it completely or by modifying its dissimilar parts.
- Rule Based Reasoning Module (RBR module): This module is responsible on the execution of reasoning rules elaborated by the design team in the constructed assembly ontology. These rules are based on the decision making process of the integrated DFMMA approach, in particular its assembly solution selection process. Moreover, they are expressed in SWRL (Semantic Web Rule Language)/SQWRL (Semantic Query-Enhanced Web Rule Language) and they are stored in the rules base of the developed assembly ontology.
- The Final Decision-Making Module (FDMM): This module permits to the design team to save and archive the generated results, namely, the optimal assembly solution in the case base of the ADM-Onto. So that, the designers benefit of their experience in the next studies in terms of time and consequently of money.
- The Control Module (MD): This module is responsible on the control of the consistency between all the other modules.

Fig. 1 shows the global structure of the proposed automated system for assembly solution selection.

Fig. 2 presents the working process of the proposed assembly decision-making system: the ADM system.

Indeed, after the collection of the different information that designers need to continue their study through the first module of the proposed system, the semantic model of the studied mechanical product is created. It presents the base for the PJM to decide if the process of the proposed methodology continues or not. If the result is positive, then, the CBR based decision making process is executed through the CBR module. In its turn, if the optimal assembly solution is not got, the RBR based decision making process is executed. Finally, the generated result is saved through the FDMM.

In the next sections, the working processes of the proposed system modules will be detailed.

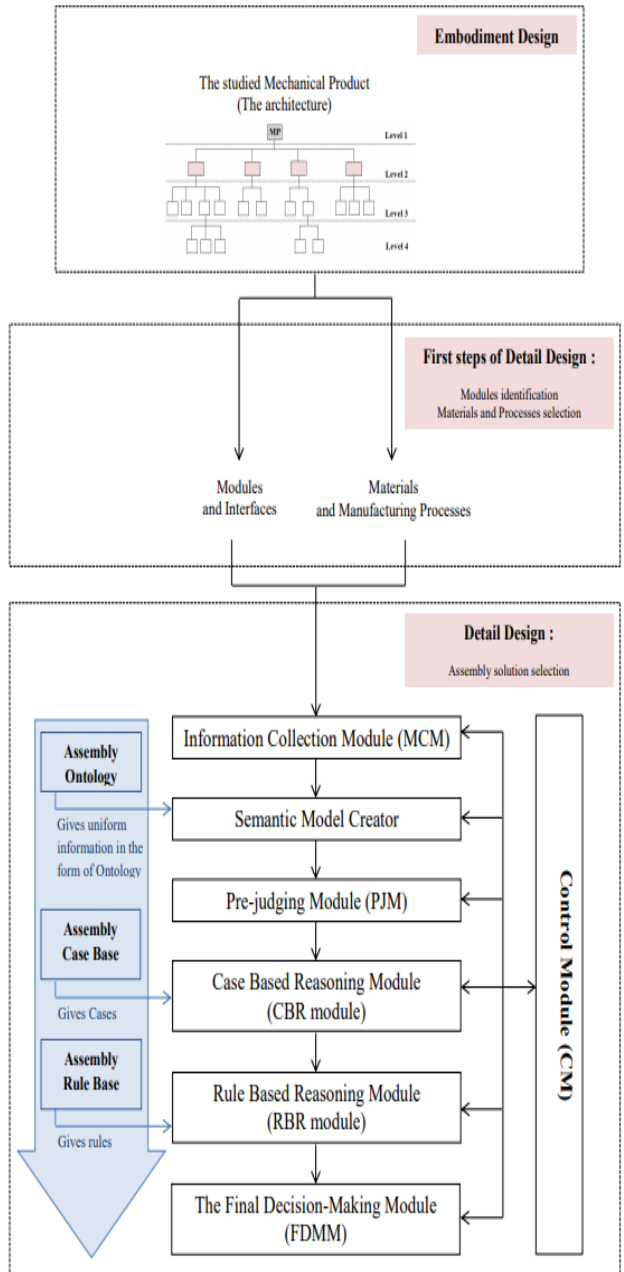

Fig. 1. The Global Structure of the Proposed Automated System for Assembly Solution Selection.

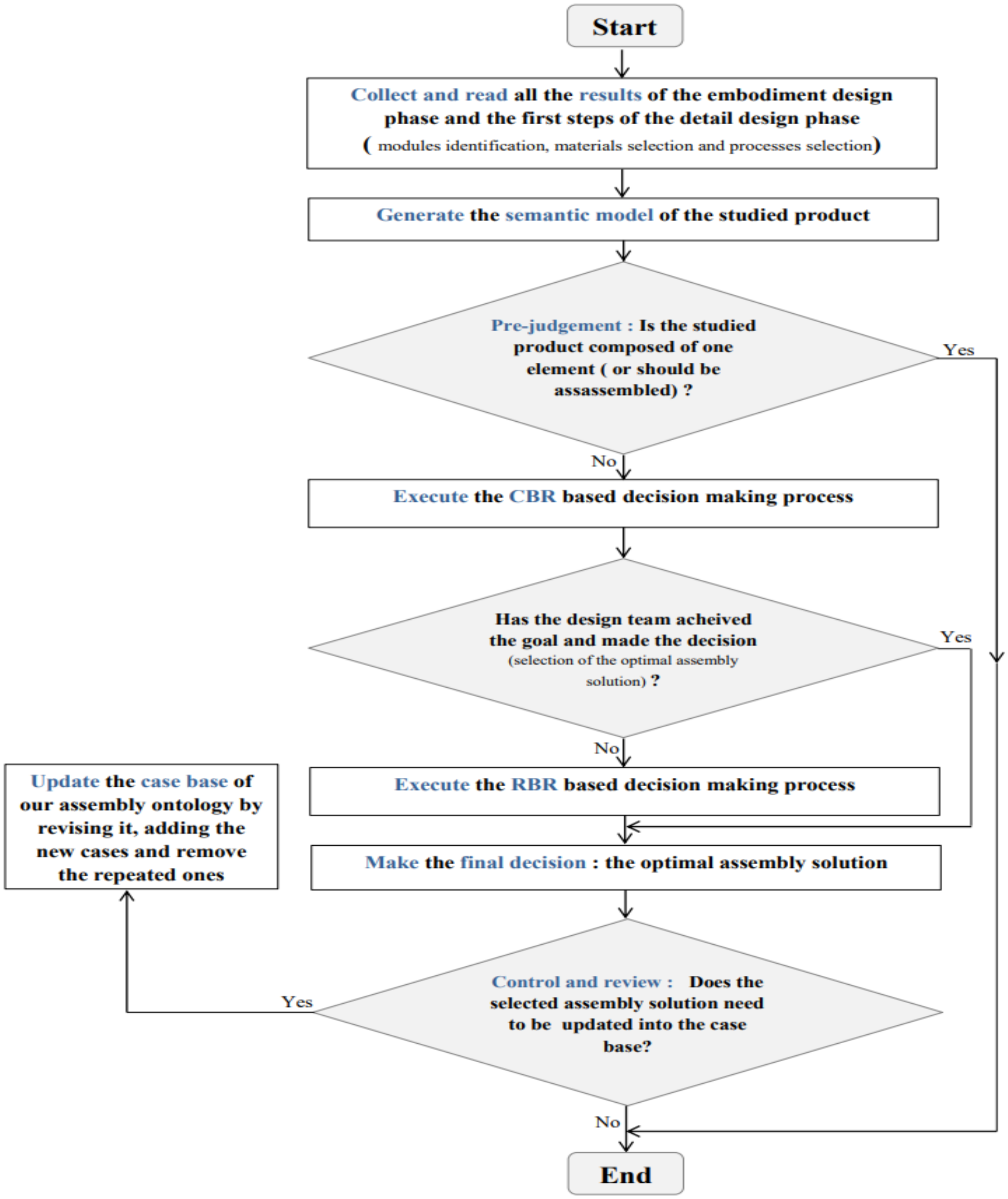

Fig. 2. The Working Process of the ADM System.

IV. Construction of the ADM-Onto and the Product Semantic Model

In this section, the assembly ontology (the ADM-Onto) is constructed to be used later by the CBR and RBR modules. In addition to that, an appropriate semantic model to the proposed ontology is developed.

A. *Construction of the ADM-Onto*

In this paper, the ADM-Onto is constructed in the Protégé ontology editor. Consequently, it is composed of three principal elements which are [31, 32]:

- Classes: They are defined as a set of individuals in a specific domain. The considered domain in our case is products assembly.
- Object properties: They define relations between classes and individuals.
- Data properties: They define modifiers for ontology classes or establish characteristics of the instances.

Thus, the first step to construct the ADM-Onto is to define its different classes as it is shown in Fig. 3. Each class except root classes (as an example: "*MechanicalProduct*" class) can be a subclass of another one. One of the originalities of the proposed ontology classes consists on the definition and use of the "*AssemblyIndicator*" class which smooth the characterization of each assembly solution (assembly alternative) with quantitative indicators. Consequently, the comparison between alternatives becomes quantified.

The definition of Object properties is the second step of the assembly ontology construction. Table II presents those different object properties, their domains, their ranges and their inverse properties.

The defined object properties can be divided into three categories:

- Object properties 1-9: they are used to define the architecture of the studied mechanical product and the different requirements that should be respected in the design study. They are used mainly in the construction of the first part of the semantic model.
- Object properties 10-17: They are used to specify the different characteristics of the mechanical product components in terms of topologies, materials and manufacturing processes. Thus, they are used in the CBR process in order to facilitate the research of the similar existing cases to the studied one.
- Object 18- 33: They are used to affect to each assembly solution the different indexes defined in the integrated DFMMA approach, in particular the assembly solution selection part; namely the quality indicator, the time indicator, the cost indicator and finally the global assembly indicator [1]. Consequently, they are used in the RBR Process in order to facilitate the comparison between different assembly alternatives.

The third step of the ADM-Onto construction is the definition of data properties as it is shown in Table III. The table presents also their ranges, their domains and their descriptions. Differently to object properties' ranges which are in form of ontology classes, the data properties ranges are data types. In other terms, they are either strings of character (string) or real numbers (float) or entire numbers (Int).

B. Product Semantic Model Generation

After the construction of the ADM-Onto, the suitable semantic model is generated through the second module of the proposed system.

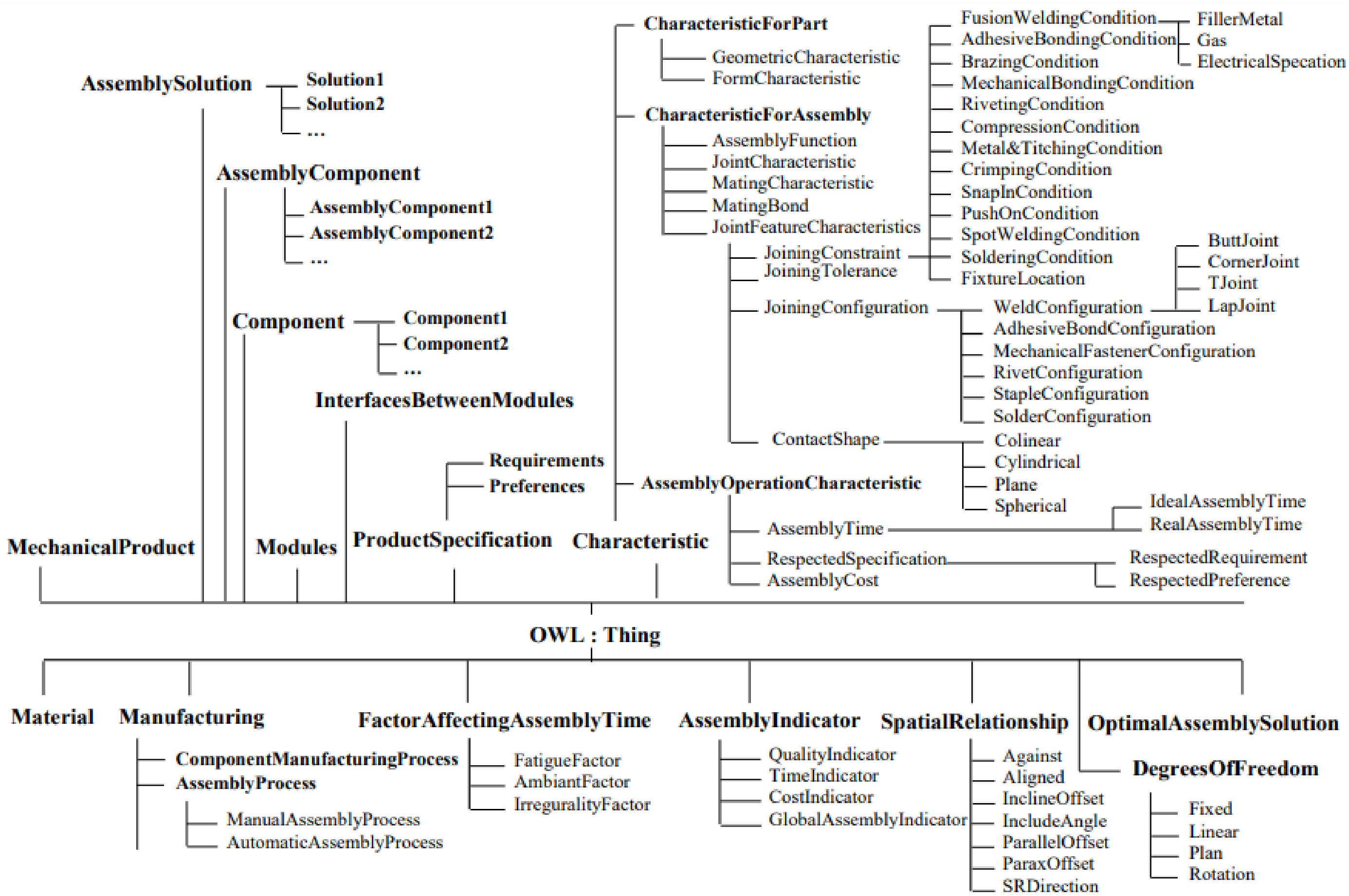

Fig. 3. Classes of the ADM-Onto.

TABLE II. OBJECT PROPERTIES OF THE ADM-ONTO

No.	Object Property	Domains	Ranges	Inverse Property
1	HasPart	MechanicalProduct	Modules InterfacesBetweenModules	IsPartOf
2	ComposedOf	MechanicalProduct	Modules InterfacesBetweenModules	IsModuleOf
3	HasComponent	Modules	Component AssemblySolution	IsComponentOf
4	HasAssemblyComponent	AssemblySolution	AssemblyComponent	IsAssemblyComponentOf
5	IsAssembledWith	Component	"another" Component	IsAssembledWith
6	IsAssemblyAlternative	AssemblySolution	MechanicalProduct	CanbeAssembledWith
7	HasSpecification	MechanicalProduct	ProductSpecification	IsSpecificationOf
8	HasRequirement	MechanicalProduct	Requirement	IsRespectedBy
9	HasPreference	MechanicalProduct	Preference	
10	BelongTo	FormCharacteristic	Component	HasFormCharacteristic
11	BelongToFormCharacteristic	GeometricCharacteristic	FormCaracteristic	HasGeometriCharacteristic
12	HasMaterial	Component AssemblyComponent	Material	IsMadeWith
13	HasReferenceDirection	MatingCharacteristic	SRDirection	IsDirectionOf
14	HasMatingComponent	MatingCharacteristic	FormCaracteristic	*****
15	HasProcess	MechanicalProduct	Manufacturing	IsProcessOf
16	HasComponentProcess	Component	ComponentManufacturingProcess	IsCompnentProcessOf
17	HasAssemblyProcess	Solution	AssemblyProcess	IsAssemblyProcessOf
18	IsDoneIn	Manufacturing	AssemblyTime	IsTimeOf
19	IsDoneInIdealTime	AssemblyProcess	IdealAssemblyTime	IsIdealAssemblyTimeOf
20	IsDoneRealTime		RealAssemblyTime	IsRealAssemblyTimeOf
21	HasRespectedSpecification	AssemblySolution	Specification	IsRespectedBy
22	HasRespectedRequirement	AssemblySolution	Requirement	
23	HasRespectedPreference	AssemblySolution	Preference	
24	HasFactorAffectingAssemblyTime	AssemblyProcess AssemblySolution	FactorAffectingAssemblyTime	IsFactorAffectingAssemblyTime
25	HasAssemblyFatigueFactor	AssemblyProcess AssemblySolution	FatigueFactor	IsFatigueFactorFor
26	HasAssemblyAmbiantFactor	AssemblyProcess AssemblySolution	AmbliantFactor	IsAmbiantFactorFor
27	HasAssemblyIrregularityFactor	AssemblyProcess AssemblySolution	IrregularityFactor	IsIrregularityFactorFor
28	HasAssemblyIndicator	AssemblyProcess AssemblySolution	AssemblyIndicator	IsAssemblyIndicatorFor
29	HasAssemblyQualityIndicator	AssemblyProcess AssemblySolution	QualityIndicator	IsQualityIndicatorFor
30	HasAssemblyTimeIndicator	AssemblyProcess AssemblySolution	TimeIndicator	IsTimeIndicatorFor
31	HasAssemblyCostIndicator	AssemblyProcess AssemblySolution	CostIndicator	IsQualityIndicatorFor
32	HasGlobalIndicator	AssemblyProcess AssemblySolution	GlobalAssemblyIndicator	IsGlobalAssemblyIndicatorFor
33	HasOptimalSolution	MechanicalProduct	OptimalAssemblySolution	IsOptimalAssemblySolutionFor

TABLE III. DATA PROPERTIES OF THE ADM-ONTO

Data Property	Domains	Range	Description
HasTechnicalFunction	MechanicalProduct Module Component AssemblyComponent	String	To indicate the technical function of the studied mechanical product/ a module/ a component/ an assembly component
IsRepeated	Module Component AssemblyComponent	Int	To record how many times the module/ the component/the assembly component is repeated in the studied mechanical product. So that, the redundancy of analysis is avoided
HasWeight	MechanicalProduct Module Component AssemblyComponent	Float	To record the weight of the studied mechanical product/ a module/ a component/ an assembly component
HasModel	MechanicalProduct Module Component AssemblyComponent	String	To record the model of the studied mechanical product/ a module/ a component/ an assembly component
IsHazardous	Material	Boolean	To indicate whether a material is hazardous
IsAssembledInPlusX	Module AssemblyComponent Component	Boolean	To record the assembly-direction(s) of a module/ an assembly component/ a component
IsAssembledInMinusX			
IsAssembledInPlusY			
IsAssembledInMinusY			
IsAssembledInPlusZ			
IsAssembledInMinusZ			
HasSimiliratyMemoryIndex	MechanicalProduct	Float	This property is used to realize the case updating strategy
IsManualProcess	AssemblyProcess	Boolean	To indicate if the assembly process is manual or automatic
IsAutomaticProcess	AssemblyProcess	Boolean	
HasNbrOfRespectedRequirement	Solution	Int	To record the number of requirement respected by the solution
HasNbrOfRequirement	MechanicalProduct	Int	To record the number of requirement imposed by costumers
HasState	Solution	Boolean	This property is used in the RBR process
HasNbrOfRespectedSpecification	Solution	Int	To record the number of specifications respected by the solution
HasNbrOfSpecificaion	MechanicalProduct	Int	To record the number of specifications imposed by the design team at the beginning of the design study
HasQualityIndicator	Solution	Float	This property is used to calculate the quality indicator of the solution
HasFatigueFactor	Solution	Float	To record the fatigue factor of the solution
HasAmbiantFactor	Solution	Float	To record the ambient factor of the solution
HasIrregularityFactor	Solution	Float	To record the irregularity factor of the solution
HasIdealTime	Solution	Float	To record the ideal time to realize the solution
HasRealTime	Solution	Float	To record the real time to realize the solution
HasTimeIndicator	Solution	Float	This property is used to calculate the time indicator of the solution
HasTotalAssemblyCost	Solution	Float	To record the total assembly cost of a solution
HasTotalAverageCostOf Production	MechanicalProduct	Float	To record the total average cost of production of the studied mechanical product imposed by the design team at the beginning of the design study
HasCostIndicator	Solution	Float	This property is used to calculate the cost indicator of the solution
HasGlobalAssemblyIndicator	Solution	Float	This property is used to calculate the global indicator of the solution
HasHighestGlobalIndicator	Solution	Boolean	this property is used to indicate the solution, that has the highest global indicator, which is the optimal one

The generated semantic model of an assembly case is presented in Fig. 4. It is compound of two parts:

- The semantic model of the studied mechanical product:

This first part describes the structure of the product (its architecture). In fact, through the "HasPart" object property, relations between the different product components are defined. This relations definition is done at two levels: the "MechanicalProduct/Module" level that records the different modules which compose the Mechanical Product; and the "Module/Component" level which records the different components that compose each module. By its turn, each product component can be decomposed to different subcomponents.

- The semantic model of the optimal assembly solution:

This second part is the continuity of the first part (The semantic model of the studied mechanical product) work.

In this part, the "IsAssembledWith" object property defines two types of relations: Module/Module relation which record modules that should be assembled together; and Component/component relation which record components that should be assembled with each other and their natures. The "InterfacesBetweenModules" class plays also a key role in the definition of the first relation (Module/Module) in terms of types and numbers of links between the studied product modules. Brief, this first part of the optimal assembly solution semantic model allows the definition of the different connections' types between modules and components.

For the second part of the optimal assembly solution semantic model, the goal is to define the different assembly alternatives of the studied mechanical product. This purpose is achieved through the "IsAssemblyAlternative" object property and the "HasGlobalAssemblyIndicator" data property. It is in this part that the different assembly alternatives are ranked.

Then, by the combination of those two parts, the optimal assembly solution is obtained. This result is got through also the help of the "HasOptimalSolution" object property and the "HasHighestGlobalIndicator" data property that affects the optimal solution S* to the one that has the highest global indicator value.

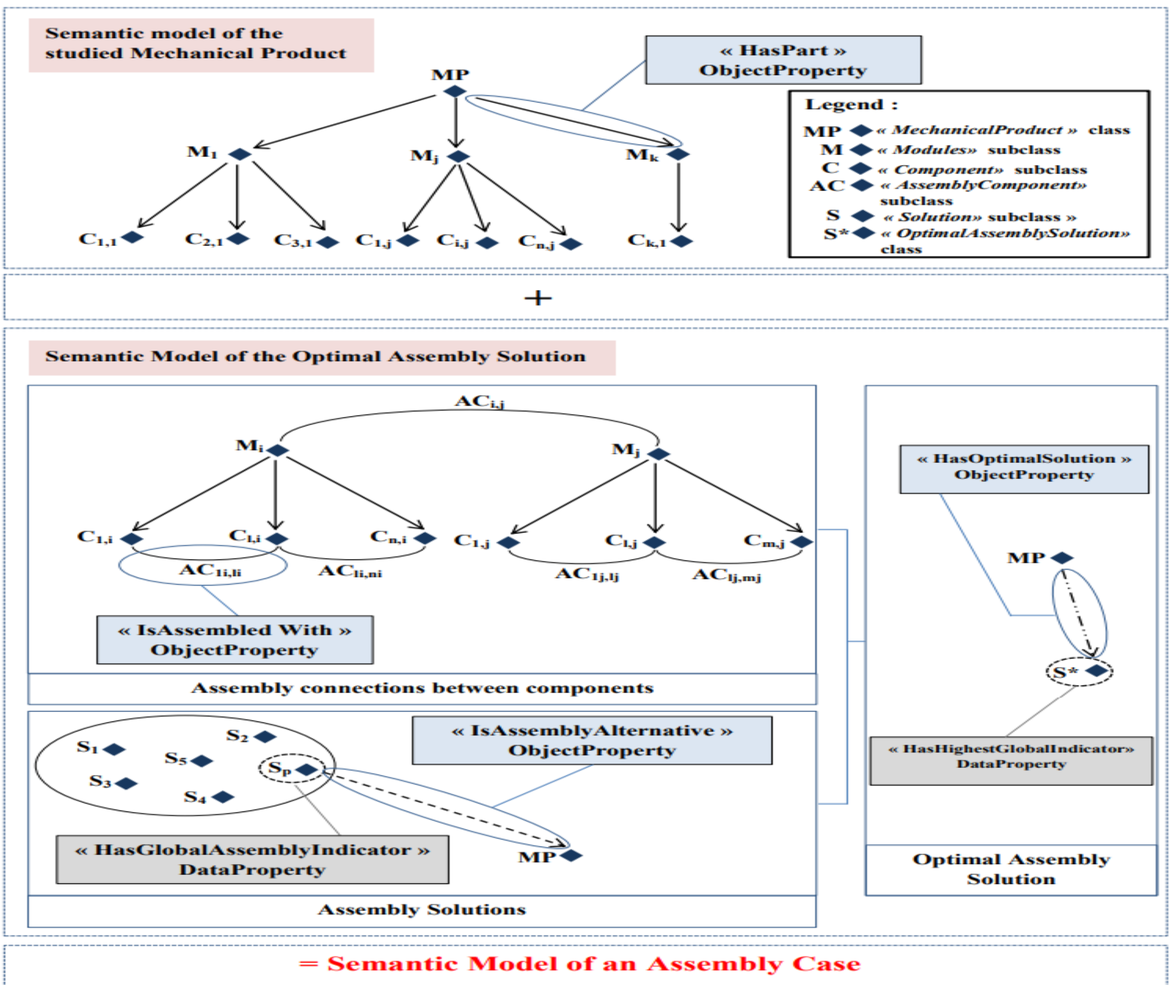

Fig. 4. Semantic Model of an Assembly Case.

V. Description of the Case-Based Reasoning (CBR) Module for Optimal Assembly Solution Selection

The CBR module aims to use the previous cases of assembly solution selection studies in a new case. Thus, this module is based on a base case that contains the archive of studies done previously by the design team.

In this section, the adopted notation is as follow:

- b : number of case studies belonging to the case base
- CS_t : Case Study NO t belonging to the case base with t=1…..b
- k : number of modules of the studied mechanical product
- M_j : Module number j , j=1……,k
- m_j : Total number of M_j components
- C_{ij} : The product component number i of module j with i=1,……m_j and j=1,….k
- l_j : Number of the similar modules to M_j
- $M_{j,sl}$:The similar module number l to Mj with 1=1…..l_j
- n_{jl} : Number of M_j component that have similar one in $M_{j,sl}$
- $C_{ij,st}$: A component C_{ij} that has similar one in the case study C_{St}
- $C_{ij,ns,d}$:A component C_{ij} that has no similar one in the case base number d
- $AC_{il,j}$: Assembly connection between C_{ij} and C_{il}
- r_j: total number of connections in M_j
- $AC_{il,j,st}$: A similar assembly connection to ACil,j in CS_t
- e_{jl} : Number of M_j assembly connections that have similar one in $M_{j,sl}$
- $AC_{il,j,np}$: An assembly connection $AC_{il,j}$ that has no similar one in CS_p
- M_j* : The most similar case to M_j
- S_j* : The set of the similar components and connections in M_j to the ones in M_j*
- NS_j* : The set of the remaining components and connections in M_j (the ones that not have similarities in M_j*)

Fig. 5 presents the proposed working process of the CBR module.

The first step in the CBR process is to search, in the base case, the most similar cases to the studied one. To do this, the research will be done per module. In fact, for each module Mj, an analysis is done in the ADM-Onto memory to check if similar modules, that are composed of similar components and connections and that can ensure the same functions with some minor modifications, have been previously developed by the design team. This operation is done by considering firstly the previous complete cases/studies as an individual of the MechanicalProduct class. Then, designers have to use three different elements, in order to determine cases that should be compared to the studied module Mj, namely:

- The Module class name as an index
- The "HasPart", the "IsAssembledWith", the "BelongTo", the "BelongToForm", the "HasMaterial", the "IsManufacturedUsing" and the "HasProcess" object properties
- The "HasTechnicalFunction" and the "HasModel" data properties.

By determining all the alternatives, the case-comparison is the next step in the CBR process. In this context, a Similarity Memory Index (SI) is proposed. It is based on two sides which are the similarities between M_j and $M_{j,sl}$ modules in terms of similar components and similar connections.

It is to note that $AC_{ik,j,sl}$ refers to the existence of a similar connected components to C_{ij} and C_{kj} in $M_{j,sl}$ in terms of connections. In other terms, C_{ij} and C_{kj} should have the same technical functions to their similar components and the same degrees of freedom to remove/ to block in order to ensure the assembly solution.

So for each alternative $M_{j,sl,}$ SI is computed using the following formula:

$$SI_{j,l} = \frac{1}{2} * \left(\frac{n_{jl}}{m_j} + \frac{e_{jl}}{r_j}\right) \quad (2)$$

The most similar module to the studied one M_j is the one that has the higher SI value: $M_{j,s}$ *.

By determining $M_{j,s}$* , Two cases are supposed to have:

- SI=1: which means that M_j and M_j* are totally similar. In this case, designers should reuse and extract the optimal assembly solution from M_j*.
- 0<SI<1: which means that Mj and M_j* are not totally similar. In this case, designers should extract the optimal assembly solution from M_j* for the set of the similar components and connections S_j*. Then, they apply the RBR method to determine the optimal assembly solution for the set of the remaining components and connections NS_j*.

The execution of the CBR decision-making process for optimal assembly solution selection is based on a main principal: the ADM-Onto can express cases in different granularity. In fact, a module of the *MechanicalProduct* class can be a complete previous product/case (which contains in its turn multiple components/ sub-assemblies) and each two assembled individuals has a corresponding optimal assembly solution.

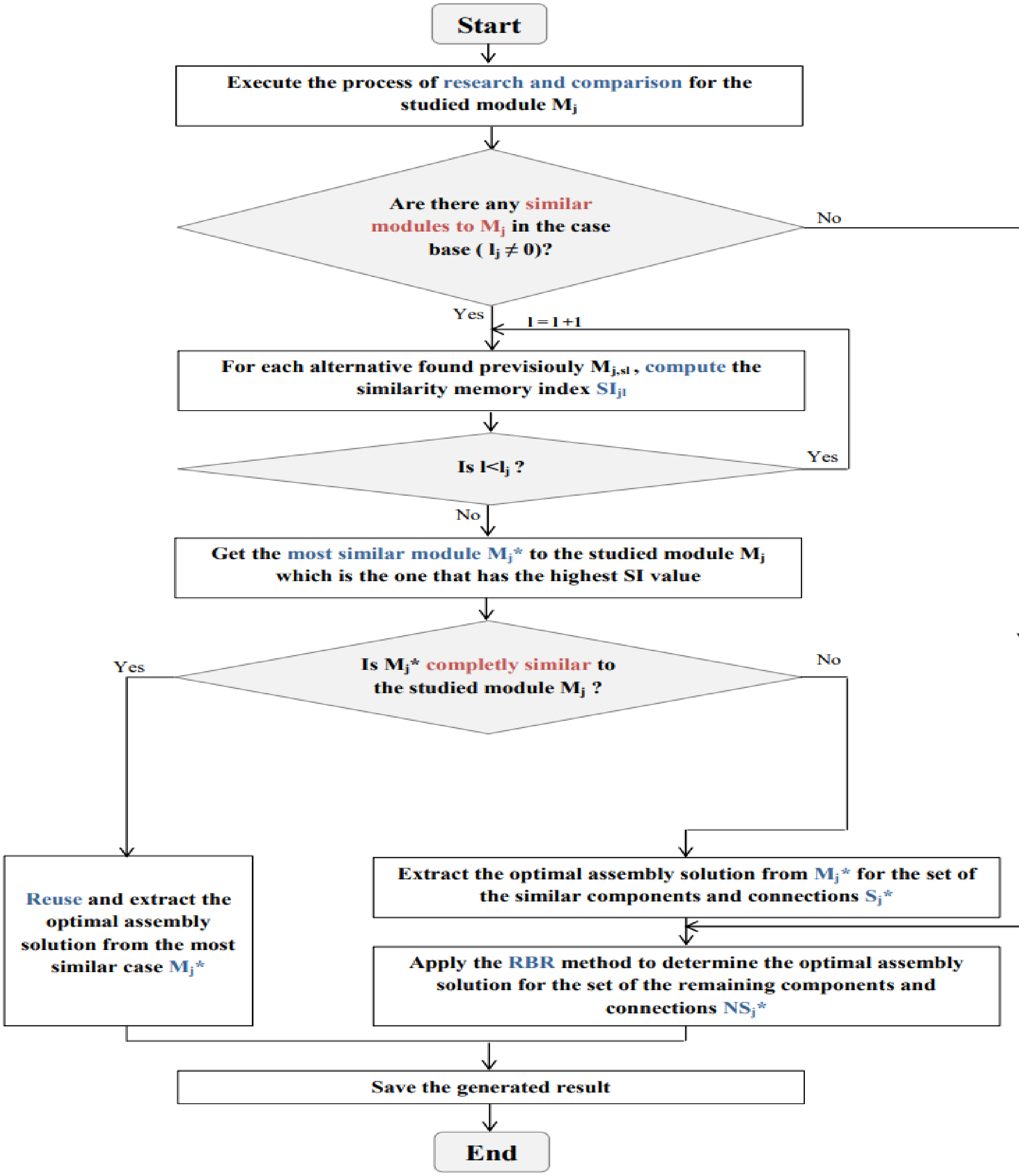

Fig. 5. The Proposed CBR based Decision-Making Process for Optimal Assembly Solution Selection.

VI. Description of the Rule-Based Reasoning (RBR) Module for Optimal Assembly Solution Selection

The use of the RBR module is the second solution to select the optimal assembly alternative if the CBR module does not succeed to do it. In fact, as its name indicates, the RBR module is based on a rules base that designers should define and execute on the ADM-Onto in order to obtain automatically the optimal assembly solution of the studied mechanical product.

In the proposed RBR module, the integrated DFMMA, in particular its proposed assembly solution selection methodology is the base of the defined rules as shown in Table IV.

In addition to that, those rules are expressed using SWRL/SQWRL [33-35]. Thus, the listed rules are in the form of implication between an antecedent and its consequence.

So, if antecedent conditions hold (are "True"), then the consequent conditions must also hold. In SWRL, rules parts, i.e. their antecedent and their consequents, are formed basing on a set of axioms written in the following form: a1^.....^an. Each axiom refers to individuals, data literals, individual variables or data variables. All those variables are defined in the standard convention form that consists on prefixing them with a question mark (e.g. ?V).

The proposed working process of the RBR module is presented in Fig. 6.

For each module of the studied mechanical product, the RBR working process is executed. It passes by four steps:

- Elimination of alternatives that not satisfy costumers' requirement:

In effect, the execution of rules 1 and 2 classifies the different assembly alternatives of the studied module in function of their satisfaction of costumers' requirements. The result of this two rules is given by affecting the "0" value to the data property "HasState" for alternatives that not satisfy them and the "1" value for the other ones. Then, to eliminate the first category of alternatives, the rule 3 is executed. It aims to affect the value "0" to their related "HasGlobalAssemblyIndicator" data property ranges. Thus, all those alternatives will have automatically the lowest global indicator value and will be eliminated.

- Computation of indicators for the remaining alternatives:

This step is succeeded through the execution of rules 4, 5, 6 and 7. In fact, it aims to compute in an automatic way the four assembly indicators for alternatives that have "HasState = 1" data property (i.e. that satisfies costumers requirements) notably the quality indicator, the time indicator, the cost indicator and finally the global assembly indicator.

Those indexes are the base of selection according to the integrated DFMMA approach, in particular the optimal assembly solution selection part.

- Rank of alternatives basing on their global assembly indicator:

This step is based on the results of the previous step. Actually, it aims to rank alternatives from the one that has the higher global assembly indicator to the one that has the lower one.

- Identification of the optimal alternative and save the generated result:

This step is the last one in the RBR process. It aims to relate the studied "module" class to the "optimalAssemblySolution" class through the "HasOptimalSolution" object property and the "HasHighestGlobalIndicator" data property. Then, the result of the study, namely the optimal assembly solution of the studied module, is saved in the case base of the ADM-Onto. This saved result can be used and can help the team design later to solve other new cases by executing the CBR process. Thus, this step plays a key role to save time and consequently money in the future design studies.

TABLE IV. ASSEMBLY EXECUTED RULES OF THE PROPOSED RBR MODULE

NO	Rules
1	AssemblySolution(?S) ^HasNbrOfRespectedRequirement(?S, ?r) ^ MechanicalProduct(?P) ^ HasNbrOfRequirement(?P, ?n)^ IsAssemblyAlternative(?S, ?P) ^ swrlb: lessThan (?r, ?n) ^ → HasState(?S, 0)
2	AssemblySolution(?S) ^HasNbrOfRespectedRequirement(?S, ?r) ^ MechanicalProduct(?P) ^ HasNbrOfRequirement(?P, ?n)^ IsAssemblyAlternative(?S, ?P) ^ swrlb:equal(?r, ?n) ^ → HasState(?S, 1)
3	AssemblySolution(?S) ^ HasState(?S, 0) → HasGlobalAssemblyIndicator(?S, 0)
4	AssemblySolution(?S) ^ HasState(?S, 1) ^ HasNbrOfRespectedSpecification(?S, ?N) ^ MechanicalProduct(?P) ^ HasNbrOfSpecification(?P, ?M) ^ swrlb:divide(?t, ?N, ?M) ^ swrlb:multiply(?Q, ?t, 100) → HasQualityIndicator(?S, ?Q) ^ sqwrl:select(?S, ?Q) ^ sqwrl:columnNames("Assembly Alternative", "Quality Indicator_in %")
5	AssemblySolution(?S) ^ HasState(?S,1) ^ HasFatigueFactor(?S,?Ffa) ^ HasAmbiantFactor(?S, ?Fam) ^ HasIrregularityFactor(?S,?Fir) ^ hasIdealTime(?S, ?Tid) ^ HasRealTime(?S, ?Tre) ^ swrlb:multiply(?q, ?Ffa, ?Fam, ?Fir, ?Tid, 100) ^ swrlb:divide(?T,?q, ?Tre) → HasTimeIndicator(?S, ?T) ^ sqwrl:select (?S,?T)^ sqwrl:columnNames("Assembly Alternative", "Time Indicator_in %")
6	AssemblySolution(?S) ^ HasState(?S, 1) ^HasTotalAssemblyCost(?S, ?Cat) ^ HasTotalAverageCostOfProduction(?S, ?CavPro) ^ swrlb:divide(?T,?Cat, ?CavPro)^swrlb:subtract(?q , 1 , ?T) ^ swrlb:multiply(?C, ?q, 100) → HasCostIndicator(?S, ?C) ^ sqwrl:select(?S, ?C)^ sqwrl:columnNames("Assembly Alternative", "Cost Indicator_in %")
7	AssemblySolution(?S) ^ HasState(?S, 1) ^ HasQualityIndicator(?S, ?Iq) ^ HasTimeIndicator(?S,?It) ^ HasCostIndicator(?S, ?Ic)^swrlb:multiply(?a,?Iq, ?It, ?Ic)^ swrlb:divide(?G, ?a, 10000) → HasGlobalAssemblyIndicator(?S, ?G)^ sqwrl:select(?S, ?G) ^ sqwrl:columnNames("Assembly Alternative", "Global Assembly Indicator_in %")

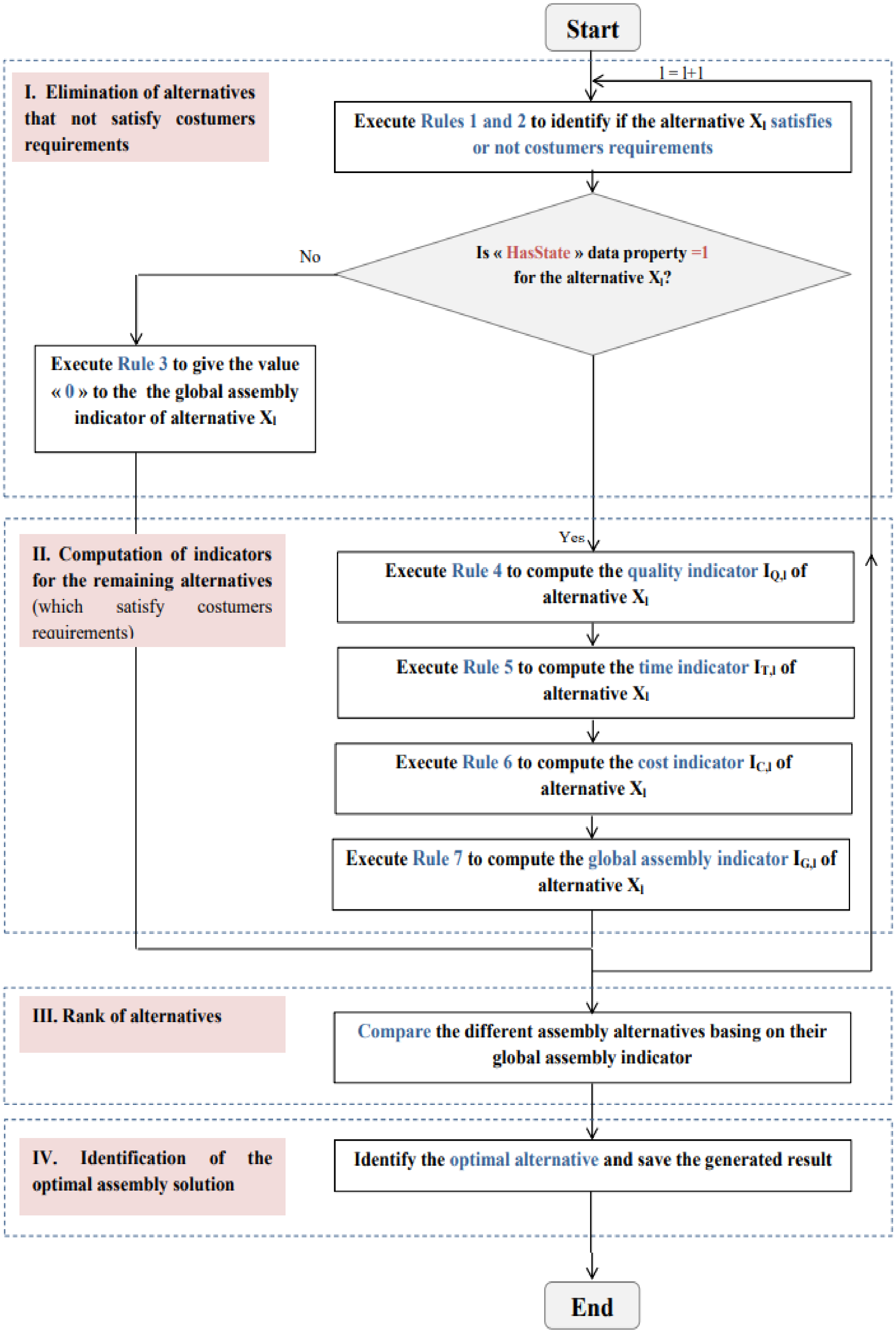

Fig. 6. The Proposed RBR based Decision-Making Process for Optimal Assembly Solution Selection for each Module of the Studied Mechanical Product.

VII. Case of Study

To illustrate the functioning and the applicability of the proposed ADM system, a case of study is presented in this section. Actually, the different steps of the proposed methodology are applied in this section on a complex mechanical product which is the Schrader robot.

The main function of this studied product is moving objects from one station to another. To ensure this function, different modules are assembled together, namely a rotating base, an elevation unit, a linear unit, a rotating wristband and finally a grip. In addition to that, according to the integrated DFMMA approach, those modules are linked with mechanical interfaces as it is shown in Fig. 7.

By defining the Schrader robot architecture, its modules and interfaces between them, its components materials and their manufacturing processes, according to the DFMMA approach [1], all the useful information to select the optimal assembly solution are collected. Thus, the first step of the ADM methodology working process is implemented.

Then, the second step, which is the construction of the ADM-Onto, is applied. Thus, all its classes, its object properties and its data properties, in addition to all their domains and their ranges are defined.

As there are no similar cases in regards to all the Schrader robot modules in the case base of the assembly ontology, the CBR process cannot be used in this case. Thus, according to the proposed methodology, the RBR process is applied to select the optimal assembly solution for all modules of the studied mechanical product.

As an example, in this paper, the grip module, which is the most important module of the Schrader robot, will be the subject of the RBR process application. The function of this module is to Grip or put down the object to be handled.

The grip module is composed of six components which are: The body, a piston, two fingers and two connecting rods. All the details of this module functioning are presented in reference 1.

In this case of study, the design team has to compare three different assembly solutions. Actually, designers have choose to assembly the body and the piston by four screw nuts; Then, to assembly the piston to the two rods with a pin clamped by both extremities of the Schrader grip body.

The unique difference between the three alternatives consists on the assembly solution between the rods and the fingers. But, to keep the balance during the functioning of the studied product in terms of mechanical efforts and also in terms of the opening and closing speed of its fingers, the same solution is used for the two sides (the lower and the upper). Thus, the three assembly alternatives between the rods and the fingers components are as following:

- Assembly by pins + circlips
- Assembly by pins + washers
- Assembly by pins + locknuts

Before executing the different previous defined rules of the RBR process, the different assembly alternatives of the grip module are defined in the constructed ADM-Onto ontology.

It is to note that the used reasoner in the constructed ADM-Onto is "Pellet". This choice is done basing firstly on the different features that presents this reasoner.

In fact, it is characterized by its consistency checking. Consequently, the constructed ontology does not contain any contradictory facts. Furthermore, the concept of satisfiability is realized because of the ability of "Pellet" reasoner to check the possibility for a class to have any instances. Another feature of this used reasoner is its capacity of classification by computing the subclass relations between every named class to create the complete class hierarchy. It is able also to compute the direct types for each of the individuals.

In addition to all those features, Pellet reasoner presents a main advantage that makes it particular. Actually, differently to the other reasonners that detect inconsistent but the diagnosis and resolution of the bug is not supported at all, Pellet contains two additional debugging services. They help the user to know the inconsistency reasons:

- The service clash detection that permits the determination of the root contradiction or clash in the completion graph;
- The axiom tracing that allows the extraction of the relevant source axioms from the ontology responsible for the clash.

As previously explained, the first stage of the RBR process is to eliminate assembly solutions that not satisfy costumers' requirements. To do so, the first defined rules are executed firstly. The results are presented in Fig. 8.

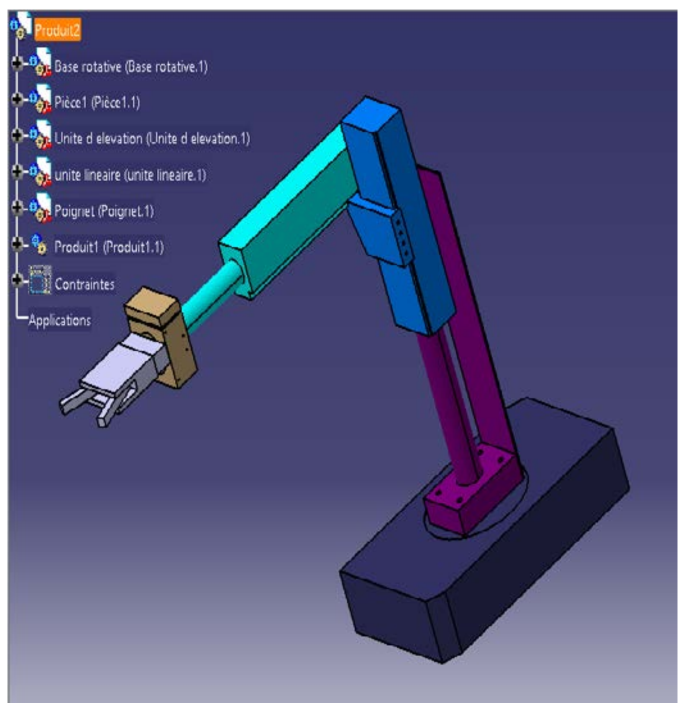

Fig. 7. The Schrader Robot Architecture: Its Different Modules.

All of the grip assembly alternatives have "*HasState =1*" data property. Consequently, any of them is eliminated by the execution of Rule 3.

The next stage is to compute the different indexes defined according to the integrated DFMMA approach, in particular its assembly solution selection methodology, by executing rules 4, 5, 6 and 7. Fig. 9, Fig. 10, Fig 11 shows respectively the different obtained values of the quality indicators, the time indicators and the cost indicators with the reasoner Pellet.

Fig. 12 presents the global assembly indicator results for all the compared grip assembly alternatives.

According to those results, designers conclude that the optimal assembly alternative is the first one since it has the highest global index (Fig. 13).

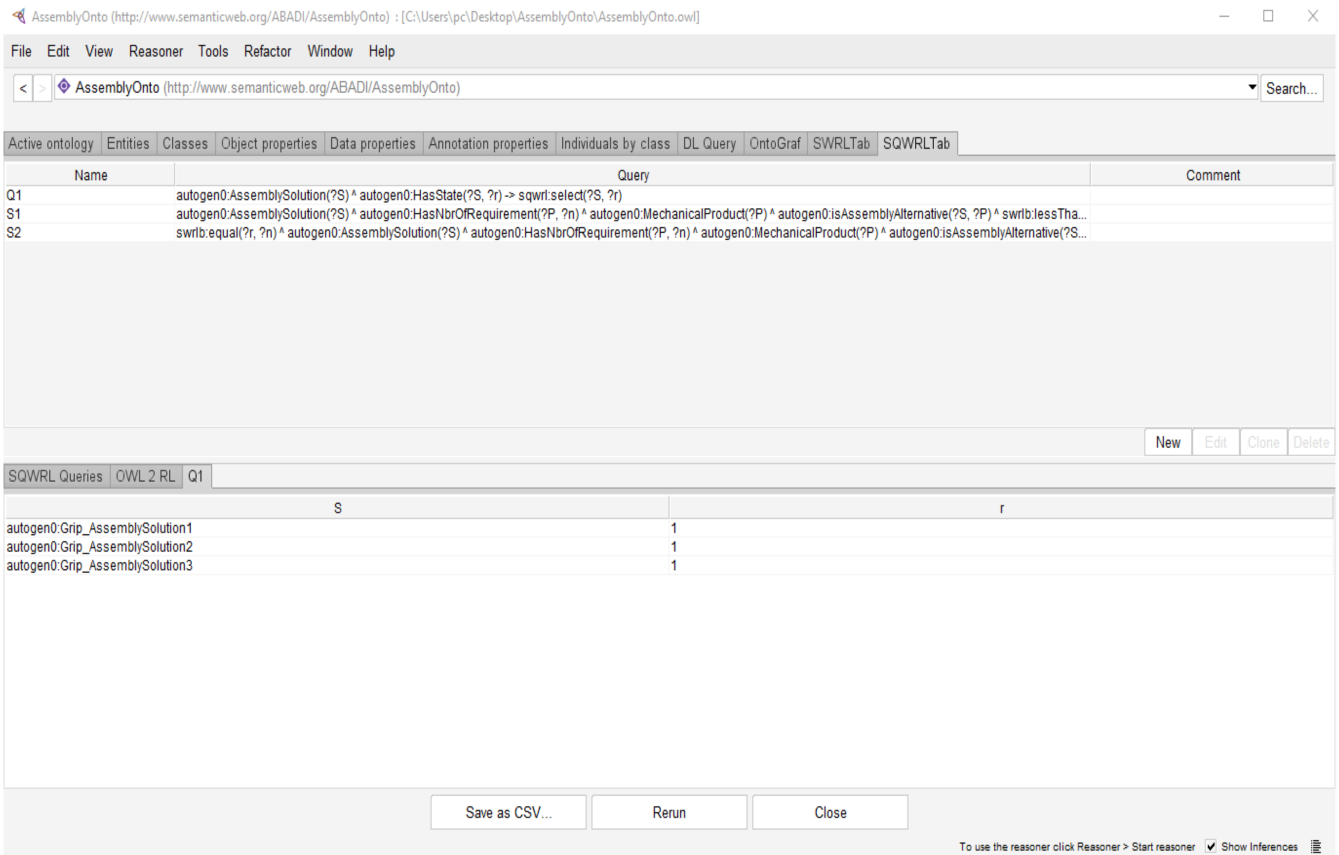

Fig. 8. Results of the First Phase of the RBR Process Application.

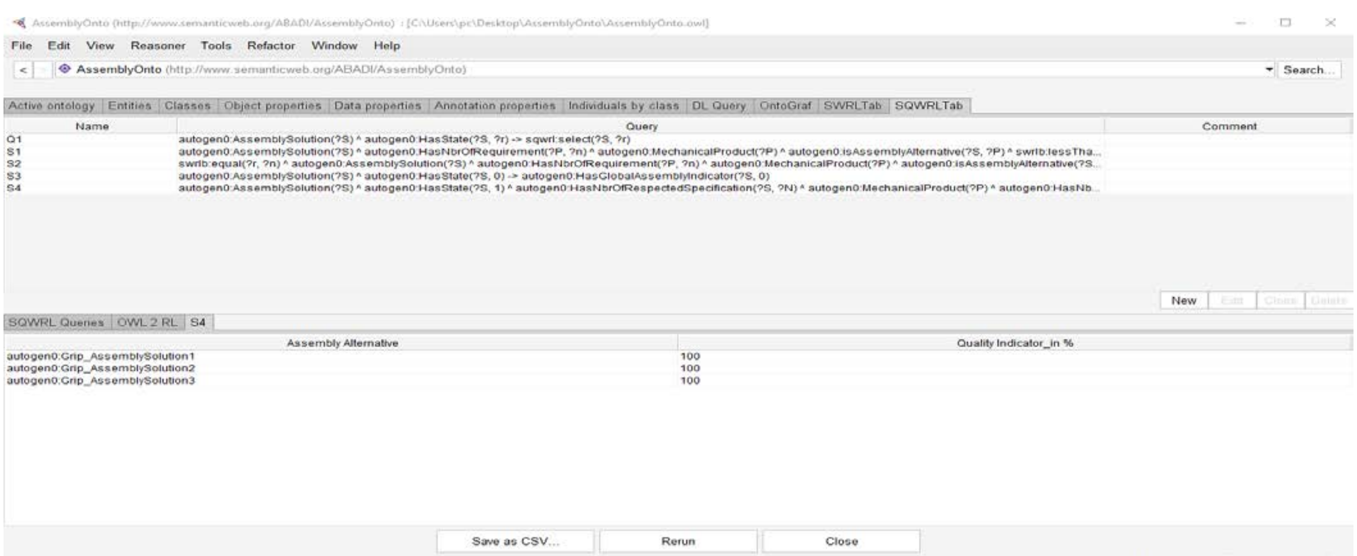

Fig. 9. Quality Indicators of the different Grip Assembly Alternatives.

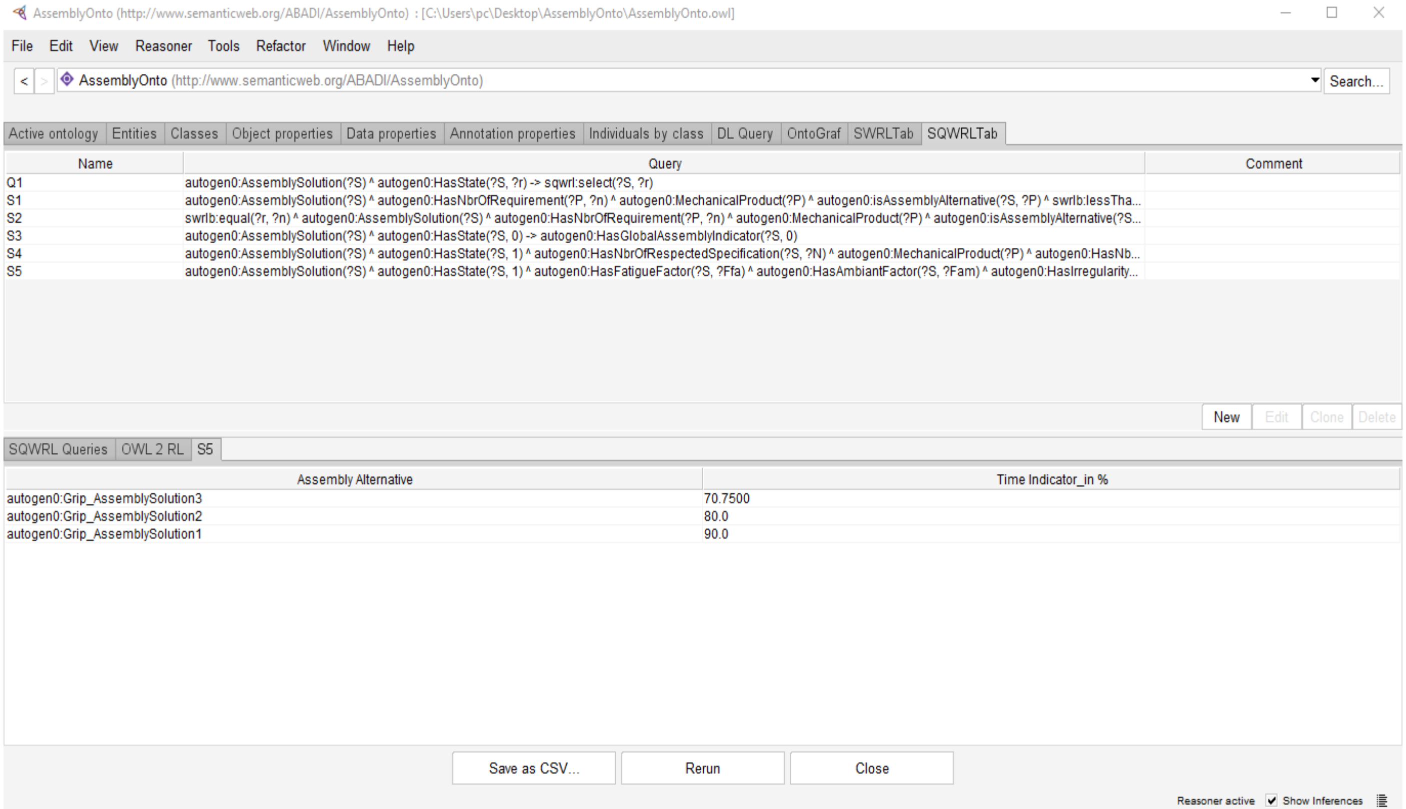

Fig. 10. Time Indicators of the Different Grip Assembly Alternatives.

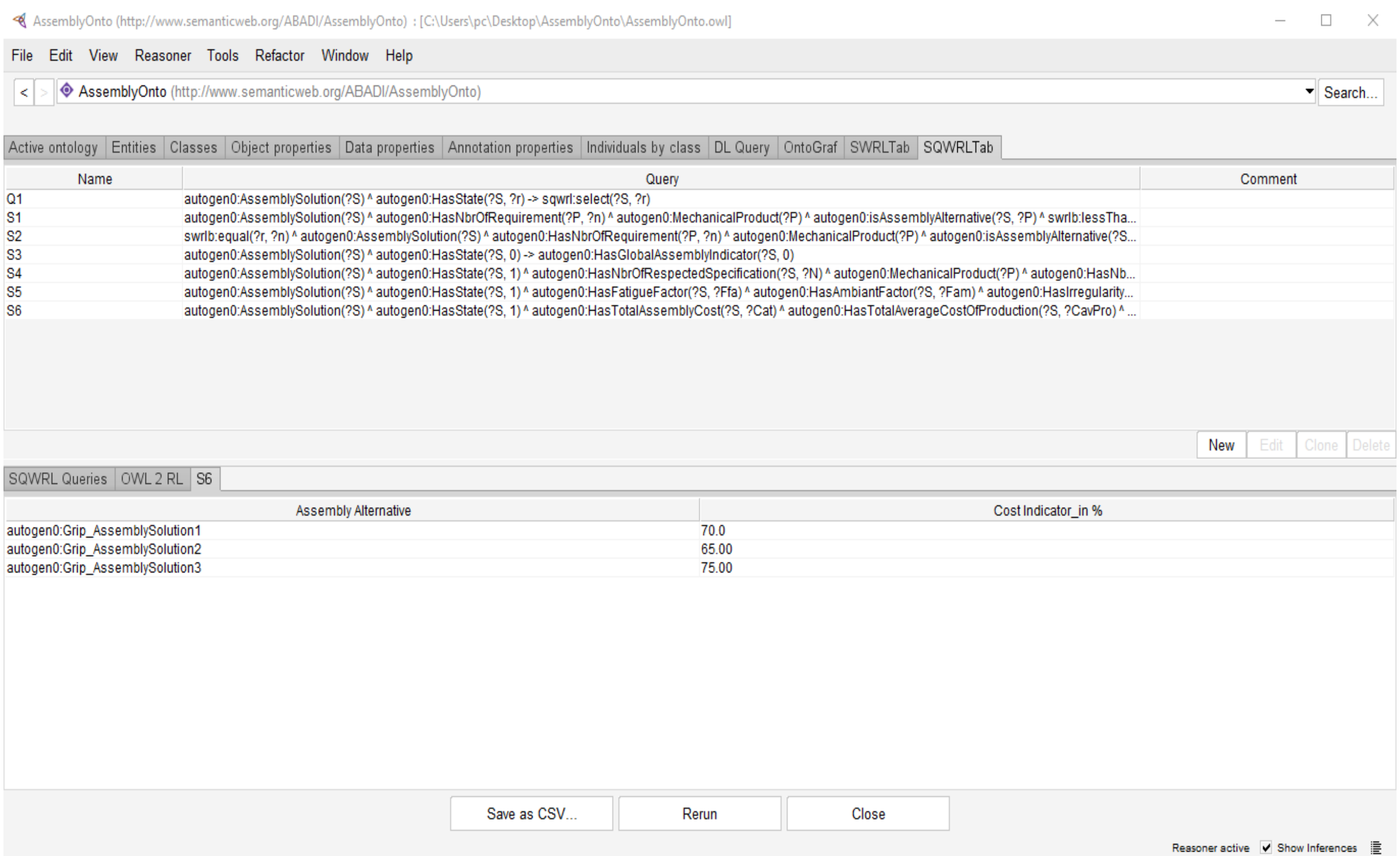

Fig. 11. Cost Indicators of the Different Grip Assembly Alternatives.

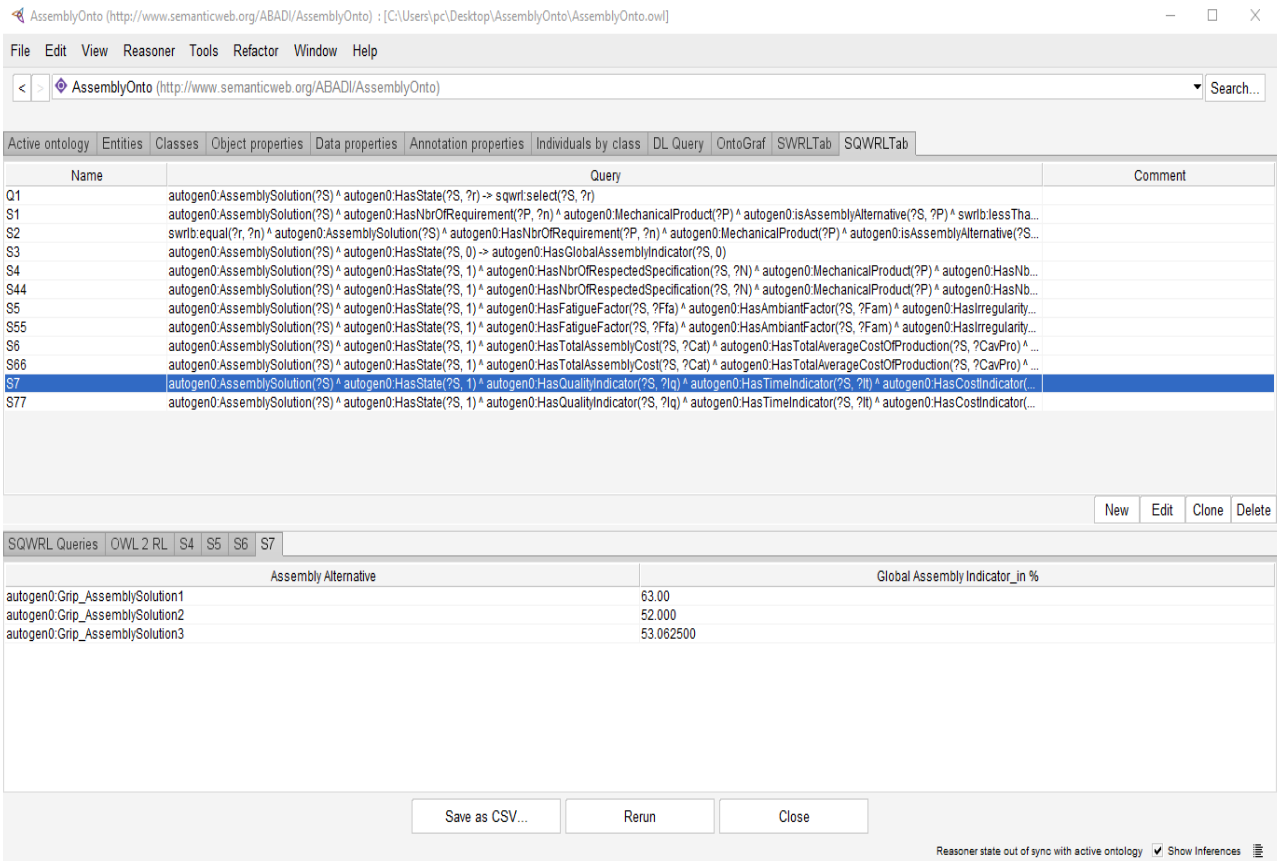

Fig. 12. Global Assembly Indicators of the Different Grip Assembly Alternatives.

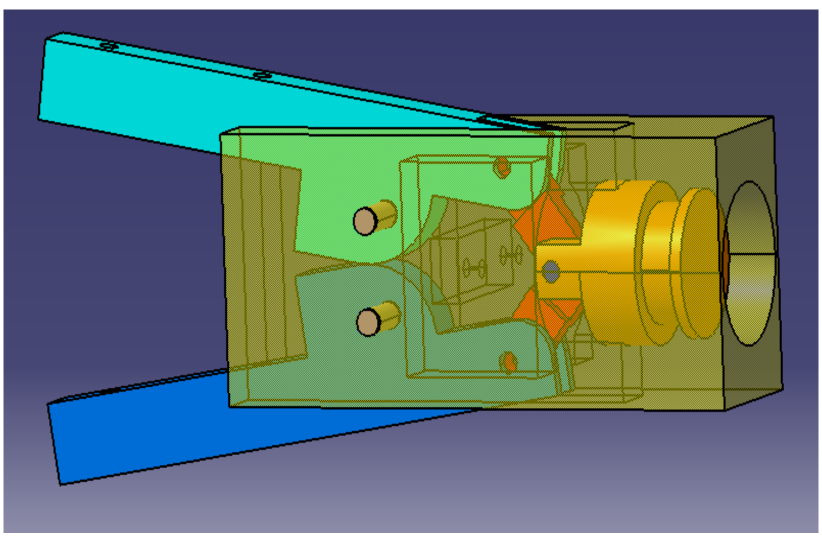

Fig. 13. The Optimal Assembly Solution of the Grip Module.

VIII. Conclusion and Perspectives

In this paper, a flexible and automated decision making system is proposed. The developed ADM system is composed of several modules and it aims to automate the selection of the optimal assembly solution. It is based on ontologies, CBR and RBR concepts. In addition to that, the proposed methodology/system is an automation of the integrated DFMMA approach, in particular its assembly solution selection methodology.

Unlike the manual assembly selection previous works, the proposed system uses the previous developed cases of the design team in the new ones and benefits from its experience basing on the Case Based Reasoning. In addition to that, through the Rule Based Reasoning used in the developed system, the selection is automatic and easy even if the number of assembly alternatives is high.

To validate all the advantages of our ADM system, a case of study is presented in the end. Actually, the ADM methodology is applied on a mechanical complex product: The Schrader Robot. The implementation of the proposed automated methodology on the considered case study permits the definition of its different modules, components and interfaces between modules in the ADM-Onto in forms of classes. In addition to that, it allows the definition of the different relations between them through different object and data properties. Finally, the selection of the optimal assembly solution is done automatically by the execution of the different rules of the ADM system RBR module.

As perspectives, it is suggested to enrich more the proposed ADM-system, in particular its ontology ADM-Onto, by integrating other aspects to the assembly solution selection, namely, the security side of assembly operations and the environmental constraints. Another perspective is to consider uncertainties that presents the design phase in the future works.

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IDP: A Privacy Provisioning Framework for TIP Attributes in Trusted Third Party-based Location-based Services Systems

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***Abstract*—Location-Based Services (LBS) System is rapidly growing due to radio communication services with wireless mobile devices having a positioning component in it. LBS System offers location-based services by knowing the actual user position. A mobile user uses LBS to access services relevant to their locations. In order to provide Point of Interest (POI), LBS confronts numerous privacy related challenges in three different formats including Non-Trusted Third Party (NTTP), Trusted Third Party (TTP), and Mobile Peer-to-Peer (P2P). The current study emphasized the TTP based LBS system where the Location server does not provide full privacy to mobile users. In TTP based LBS system, a user's privacy is concerned with personal identity, location information, and time information. In order to accomplish privacy under these concerns, state-of-the-art existing mechanisms have been reviewed. Hence, the aim to provide a promising roadmap to research and development communities for the right selection of privacy approach has achieved by conducting a comparative survey of the TTP based approaches. Leading to these privacy attributes, the current study addressed the privacy challenge by proposing a new privacy protection model named "Improved Dummy Position" (IDP) that protects TIP (Time, Identity, and Position) attributes under TTP LBS System. In order to validate the privacy level, a comparative analysis has been conducted by implementing the proposed IDP model in the simulation tool, Riverbed Modeler academic edition. The different scenarios of changing query transferring rate evaluate the performance of the proposed model. Simulation results demonstrate that our IDP could be considered as a promising model to protect user's TIP attributes in a TTP based LBS system due to better performance and improved privacy level. Further, the proposed model extensively compared with the existing work.**

Keywords*—*Location Based Services (LBS); Trusted Third Party (TTP); privacy protection goals; mobile user privacy; Improved Dummy Position (IDP); Sybil Query

I. Introduction

In recent years, location-based services (LBS) gaining popularity due to the rapid advancement of mobile phones, wireless communication, and positioning systems among users [1]. In Location-based services, the mobile user can get his/her current location from GPS available in their mobile phone, posting a query for services to LBS System that contains his actual location. LBS returns point of interest (POI) to a user based on his/her request. It can be used to trace the nearest cinema, restaurant, hospital, or desired destination from your location according to the shortest route. Some examples of such requests include points of interest (POI) queries, for example, "Which Chinese food restaurant is near to my current location?" queries of real-time traffic, "How swarming is the way from my house to my office?" [2], and data processing over Fog [63], cloud [64].

The essential origin of the LBS system was the Enhanced E911 authorization, passed in 1996 by the government of the U.S [29]. This authorization for operators of the mobile network distinguish emergency callers with efficiency, so the location of the caller is distributing to public safety answering points. Cellular machinery could not fulfill these certainty needs, so the operators started excessive effort to introduce advanced positioning methods. Operators launched a sequence of LBSs commercial to gain a return on Enhanced 911 investments. In many cases, on request, these comprised of services that send to users a set of Point-of-Interest (POI) such as gas station, shopping mall, coffee shop, in recommender systems [62] ATM, hospitals, and clinics. After all, many users have not to seem involved in this type of LBS system that is why most operators immediately abolish their LBS contributions and cancelled relevant evolution attempts [30].

The first web-based mobile device released in 1999 has the capability of LBS named the Palm VII. TeliaSonera in Sweden (Friend Finder, house position, emergency call location) introduce the first LBS in 2001. Further, go2 with American Telephone and Telegraph Mobility in May 2002 began the first United States application of mobile local search that used Automatic Location Identification (ALI) technologies [31]. Senator Al Franken introduces the Location Privacy-Preserving Act of 2012 to modulate the transmission and distribution of user location information in the United States (US). Till 2005, the major challenge of privacy was addressed by the TTP. Later on, NTTP in LBS was introduced, and still further work and research is required to provide sufficient privacy using these two ways in LBS System.

In the LBS system, there are three technologies used in a single device: internet access in mobile, positioning component, and user-friendly interfaces. In the late 1990's mobile phones availability only provides the facility of voice and SMS. There was a lack of user interface facilities. Whereas these technologies already utilize LBS systems. After the addition of Wireless Application Protocol (WAP) and mobile phone internet, the news was, announced about the availability of general LBS Systems [32].

The primary components of an LBS System [3] are end user's Mobile devices (e.g., smartphones), Communication network to send queries and receive services, Software application presents the services, Services provider that provide requested services to end-user and a positioning component to locate the position of the user like Global Positioning System (GPS). The LBS system provides useful and suitable location information to LBS users. When a user requests for the services from the LBS system [33] concurrently, they must reveal their location information. At that time, their personal information is at a risk. With the tremendous growth of LBS services, it is a great challenge to provide useful services under a fully private environment. Fig. 1 illustrates the fundamental LBS architecture.

Conventionally, the LBS system is used in three basic categories such as Non-Trusted Third Party (NTTP), Trusted Third Party (TTP), and Mobile Peer-to-Peer based network (P2P) [4]. All these models are composed of three components as User Mobile device, Location Server, and client. The primary objective is to provide desired services or Point-of-Interest (POI) to each client interacting or making a request to the LBS system. In order to retrieve the results, the Location Server (LS) further communicates with clients to acquire the requested location. Fig. 2(a), illustrates the Non-Trusted Third Party (NTTP) model [5] where no third party involved for preserving privacy. Its minor part based on silent period, Coordinate transformation, the L4NE protocol [6], [8], Decentralization [7], [9], Cache Based Approach [11], [13], Optimal Mechanism [10], [12], Geo Indistinguishability [14], Context-Aware Privacy Protection (CAP) [15], [17], HBLP [61] and blind filtering [16] are the examples of NTTP schemes. Further, Fig. 2(b), shows the Trusted Third Party (TTP) model using an anonymizer that guarantees reliability in order to deal with k-anonymity [18], [20], mix zone [21], dummy position models [19], [22]. Further, the third category mobile Peer-to-Peer based network (P2P) presented in Fig. 2(c) where, there is no secure transmission infrastructure, client-server, and centralized/distributed architecture. Every mobile user device interacts with another mobile user for the desired location or Point-of-interest (POI) [23].

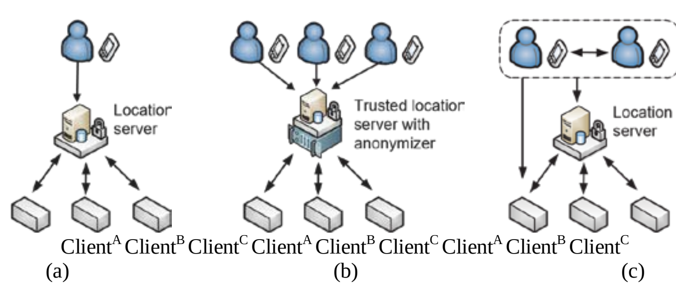
In the TTP LBS system, the Service provider is unaware of real user identity and its current location [24]. However, TTP guarantees the privacy of the mobile user using the LBS system. In our study, the main concern is to provide privacy to mobile user personal information such as his identity, spatial and temporal information in TTP Based LBS systems so that mobile users safely communicate and no one misuse their private information while accessing services [25]. For this reason, the main objective is to protect the location information and make it impractical to figure out it from many traces. However, a new privacy approach is proposed that will protect Time, Identity, and Position matrices for TTP Based LBS system. Fig. 3 comprises mobile user, communication network, positioning technology, anonymizer, service provider, and content provider.

The primary objective of the current study was to provide privacy to the mobile user in the TTP based LBS systems. Based on fundamental privacy attributes discussed in section 2, we have enhanced the "Position Dummy" model with new mechanisms to achieve our research objectives. Therefore, we have proposed a new privacy provisioning model named Improved Dummy Position (IDP). The results of this work expected to provide a proper environment to the LBS system and reduce the privacy issues between the user and Location Server (LS). However, the contribution of this paper can be summarized as follows.

- We propose an IDP System model for TTP based LBS system by extending the base Dummy Position technique, which resolves the privacy problems of the user regarding the disclosure of personal information.
- We evaluated the effectiveness of the proposed model by presenting an Improved Dummy Position (IDP) algorithm.
- In order to make sure the privacy authenticity, we implemented the proposed model in real France highway road networks using Riverbed modeler academic edition 17.5 simulation tool and measured different privacy factors including Ethernet delay, Query success rate, system performance with load and query processing time, route API retransmission and data access rate.

Further, the proposed model extensively compared with the existing work. It was observed that IDP outperformed the existing state-of-the-art models.

Fig. 1. A Common LBS Architecture.



(a) Non-trusted third party. (b) Trusted third party with anonymizer. (c) Mobile peer-to-peer network.

Fig. 2. Standard LBS Models.

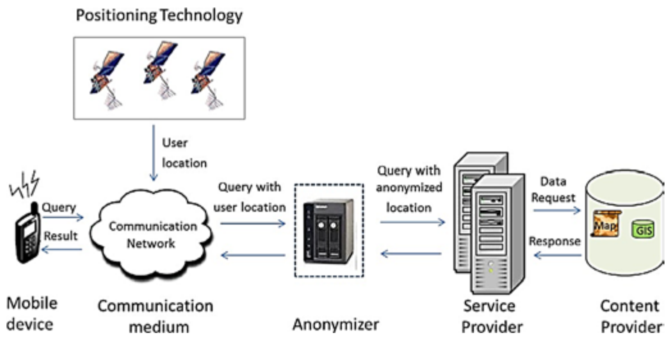


Fig. 3. An Overview of TTP LBS System.

The rest of the paper is structured as follows. Section II highlights the privacy challenges and protection goals of the TTP based LBS system. A comprehensive literature on TTP LBS models is presented in Section III. Section IV demonstrates the motivation toward the IDP system model, algorithm design, and its framework. Section V presents the experimental evaluation of the IDP scheme using simulations. Section VI highlighted the discussion. Finally, we conclude this paper and outline future work in Section VII.

II. Privacy Challenges and Protection Goals in LBS System

LBS system usage is rapidly growing nowadays but its extensive use raises many affairs. Still, LBS service providers are reluctant to build a proper environment in which they don't have an approach to user's personal information. Consciously or unconsciously, most users are ready to give one or more pieces of their personal information in order to gain new services [26], [27], [59]. User information received and saved in the LBS server can reveal extremely private information. For instance, where a user goes, whom they see, and what they do. Failing to keep this information private may threaten privacy rights. LBS server may access the user location information, which may disturb the user like the privacy of the LBS user, location information certainty, pricing, availability of data, etc. Among these challenges, "Privacy" is the critical one while using the LBS system. When a user posted a query to LBS, they send their location and related personal information to Location Server. At that time, their privacy is at the risk. These issues while using TTP Based LBS System end up with the disclosure of LBS user time of the query, their personal information (Identity), and location-related information. Therefore, these TIP (Time, Identity, Position) attributes of the LBS user need to be protected. A distinct defense against privacy issues is to exclude any data from the request that can precisely confess the LBS user identity, it is possible by using a pseudonym whenever it is needed.

In LBS System, three privacy metrics are needed to be preserved in order to provide a fully protected environment to the mobile user [25] [60]. These attributes include the user's identity, user's spatial information, and temporal information as shown in Fig. 4. The privacy of user identity means that a malicious party is unable to infer the information about the user from the previous activities. Whereas, spatial information refers to location information that puts the privacy of the user at risk. Moreover, the privacy of temporal information is to hide the time of the query from an attacker so that from time factor actual location of the user could not be disclosed. The protection of stated attributes describes the research objective which is addressed in the current study.

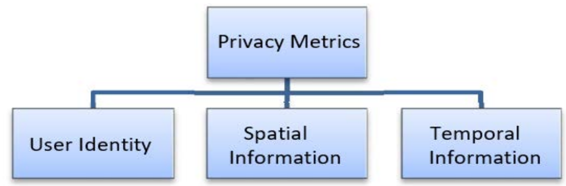


Fig. 4. LBS Privacy Metrics.

A. *UserIdentity*

The purpose is to obscure the identity of the mobile user while making a query to the LBS System so that the attacker could not reveal their identity. The identity can be a name, an ID, or any aggregation of the related key terms that are used to uniquely identify the user [28]. The disclosure of user identity can put the privacy of LBS users at risk therefore, it is necessary to preserve mobile user identity in order to save LBS users from information leakage.

B. *Spatial Information*

Another protection goal is to hide the user's actual position form the attacker. When the user makes a query to LBS they have to send their current location information to Location Server, the adversary could hack this information to locate the user and use this for the wrong purpose. Therefore, disclosing spatial information puts user privacy at risk. For instance, a person who wants to visit the nearest cafe posted a query "What is the nearest cafe from my current location". Meanwhile, to get the service he has to send his current actual position. Therefore, the privacy of spatial information is necessary for the LBS user.

C. *Temporal Information*

The intention is to hide the time information of the posted query to the LBS system. This is the time when a user making a request to LBS and sent their personal information and actual location. Therefore, the exposure of temporal information damages the user's privacy by disclosing their identity and locating his accurate position [28]. That is why the protection of temporal information is needed to provide full privacy to LBS users.

In order to achieve these three privacy metrics, there is need to depend on Trusted Third Party (TTP) where LBS System protect the information about the mobile user such as where they live, where they work and thus makes it impossible for an adversary to track the user and misuse their personal information.

III. Related Work

In order to protect a user's privacy in an LBS system, several approaches have been proposed. In this section, we have reviewed several Trusted Third Party (TTP) based techniques to preserve the privacy of the LBS user.

Location cloaking [34] mechanism uses the anonymizer (Trusted Third Party) where the cloaking region is created, and the position of a user and other k-1 neighbors kept in it. Such type of architecture is 3-tier architecture as shown in the figure below. Such type of anonymizer protects the user's identity and spatial information. The idea of K-anonymity approaches relies on the location clocking approach where the TTP LBS user's location is hiding among K-1 neighbours. Fig. 5, depicts the Location cloaking using anonymizer between user and location server. Permanent conversation and remote checking of the user is required to let the anonymizer frequently update the current position of all the subscribed users of LBS, which is the violation of the users' privacy.

Gruteser and Grunwald [35] present the concept of the K-anonymity technique. In this approach, the TTP LBS user accommodates his true position and the position of other k-1 users decides an obfuscation region. At this moment, Location Server (LS) acts as a trustworthy entity that calculates the obfuscation area that contains a mobile user's position and a set of other k users. This technique greatly protects the user's identity by a pseudonym, but it does not implement satisfactory protection across attribute disclosure.

In order to preserve the LBS user privacy, there are further approaches that are based on the concept of the k-anonymity [36]. These are strong k-anonymity, l-diversity, t-closeness, p sensitivity, historical k-anonymity. According to the Clique Cloak technique [37], [38] proposed by Gedik et al. The privacy level of k-Anonymity and some of its enhancements is to protect the user's identity and spatial information of the mobile user.

Zhang et al. [39] proposed a strong k-anonymity technique. In this technique over multiple queries, the same cluster of k users is calculated. Therefore, the attacker who calculates different clusters to infer TTP LBS users cannot identify a user. By using the concept of generalization and suppression strong k-anonymity is attaining the least misinterpret outcomes. Strong k-anonymity is not always satisfied by generalization even though all Data fly generalizations do satisfy k-anonymity. For making this heuristic-based approach more work is required.

Bamba et al. proposed the concept of l-diversity [40]. This approach ensures that the TTP LBS user's position is identical and the position of k users is evenly scattered at a certain distance from each other's. The sensitivity level of each attribute is high in this technique. Therefore, it desires much effort to achieve privacy for LBS users. L-diversity solves attribute disclosure problem that is available in k-anonymity. But l-diversity may be unnecessary to achieve. Fig. 6 illustrate the privacy provision by k-anonymity and l-diversity.

The perception of t-closeness suggested by Li et al. [41], enlarges the concept of l-diversity. It assures the distance between the distribution of sensitive attributes and the distribution of attributes within the k user's cluster. This area should not be lesser than a threshold. T-closeness can be applied using distance measures like Earthmover's distance (EMD).

Domingo-Ferrer et al presented the concept of p-sensitivity [42]. Its concept is that there are different values of p for each confidential attribute sharing a mixture of key attributes within the record. It protects from location attack by de-linking each user query from his generator, which distracts the attacker that there are several users available in a particular clocking region (CR). It provides an efficient way to determine the sensitivity of parameters with respect to the output. Information loss is higher when p-sensitive is enforced on a dataset compared to when the dataset is masked according to k-anonymity only.

Mascetti et al. [43] guarantee historical k-anonymity, which expands the concept of k-anonymity for moving objects. From Fig. 7, it is clear that the user is continuously moving from one place to another. In this approach, the system holds the record of each user movement, his history, and for creating the anonymity area main this moment history information. Hence, this anonymity area is sent to the TTP LBS system to gain the services against the request. Therefore, this is a convenient approach for preserving user position using the k-anonymity framework.

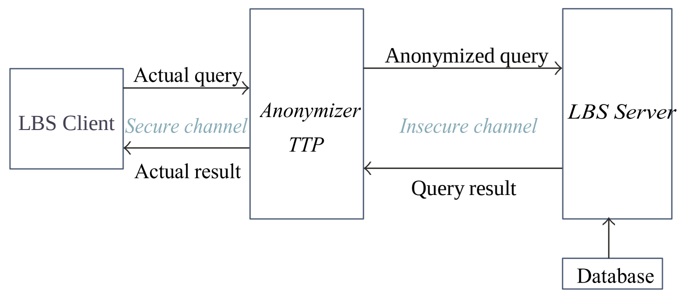


Fig. 5. Location Cloaking using Anonymizer between LBS user and Location Server.

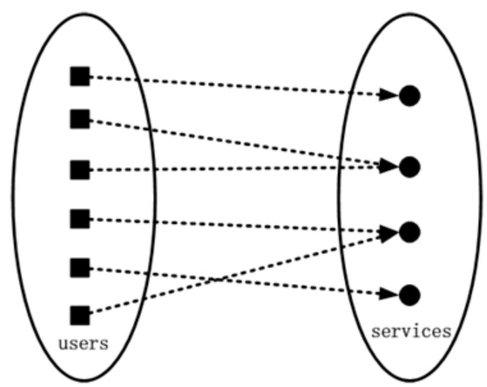


Fig. 6. Privacy Provision by K-Anonymity and l-Diversity.

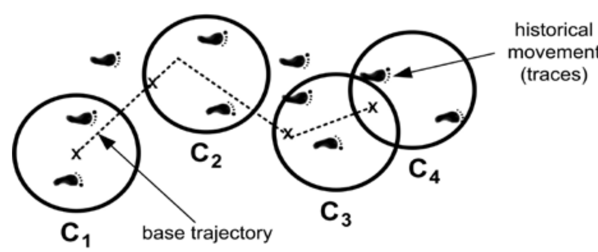


Fig. 7. K-Anonymity based on Historical Movement.

Kido et al. [44], [49] proposed the Position dummies technique which is considered as one of the reliable approaches for location protection. The main principle of the dummy position approach is defined as mobile users dispatch their current position along with multiple fake locations where mobile users' precise information is identical, thus posting a query to Location Server (LS) [50]. But at the same time it is a challenge to create non-distinguished dummies from the actual user position. In particular, if an attacker is able to track the user for a longer time and has context information about the user. When TTP LBS user changes his position and moves from X to Y, he posts a new request by sending his actual location along with new multiple false dummies according to new event or destination as shown in Fig. 8.

The advanced method to generate dummies is Sybil Query presented by Shankar et al [45]. It is a client-side tool where a user has a historic traffic database that allows them to generate multiple distinguishable dummies for the mobile user. For example, a Mobile user request for a TTP LBS server for a busy downtown area. Sybil queries will generate dummies that are from the related traffic area and conditions. Sybil Query delivers these queries to the TTP LBS system, which is incapable to differentiate the actual query from the synthetic queries [51].

Beresford presents a novel approach as "Mix Zone" for location privacy protection [46]. The fundamental concept of this technique was to hide the mobile user's actual location in a special region where others do not know that users position; an attacker could not identify who is continuously posting queries to TTP Based LBS System. In this way, TTP LBS user identity and spatial information have preserved under this mechanism. Mix zones are replacing the concept of the Spatial Cloaking technique and provide protection against location privacy. Existing mix-zone ideas fail to provide impressive mix zone construction algorithms that are effective for mobile users moving on road networks.

Palanisamy and Liu. [47] Proposed MobiMix approach. Its concept follows the mix zone technique where an attacker could exploit the personal detail such as TTP LBS user's identity, temporal and spatial information by analysis, and take full advantage largely. It is possible due to the timing of the mobile user when he enters in zone A and exit from zone A to zone B. This assist the attacker to easily identify the new and old pseudonyms.

Jiang et al. [48] proposed policy-based schemes. Policies are the statements, which determine what service provider can do with the Mobile users' private information. These policies are issued by the Service provider. If the provider does not follow these policies, then the user has the right to take legal action against the service provider. TTP LBS user has numerous policies, it's up to the user's hand to control what data is collected and with whom it would be shared. To choose policy among a number of policies, choose a policy that saves money and does not expose a user's personal data to the third person but as response service providers can hand over the user data to others in exchange for money.

Pseudonymisers [48] is a trusted third party, which acts as an intermediate among service providers and mobile users. It receives a request from the user, replaces actual user IDs with the fake ones, and sends it to the service provider. Therefore, the service provider does not know the real ID of the LBS user because it remains private. In this technique user, fully trust on it that is why Real IDs and related pseudonyms are stored in Pseudonymisers and t sent to the system to gain the services for the user, but the service provider could infer the real identity of the LBS user by linking the locations of the user.

Route Server [4] preserve the mobile user's identity and spatial information by providing accurate and efficient results for requests. To post a route request there are queries of Q set q1, q2, q3 . . . Qn, at this junction each query (q) belongs to set Q, it allows an adversary to generate some wrong information by acknowledging the user's actual location information. The challenge was provisioning privacy to the mobile users from an attacker who will conclude the wrong data in actual data when the LBS user posted a query to the system [52].To improve privacy, the Route Server (RS) algorithm has proposed a new authentic approach/technique, which is AES-RS architecture.

AES-RS architecture [4] is the enhancement of the Route Server (RS) algorithm. In this architecture, the idea of a dummy position is used where a number of dummy (fake) positions are generated along with a single user request. This architecture mainly preserves the TTP LBS users' identity and actual location from the attacker. The mechanism of this architecture is that mobile users and dummies send to the TTP LBS System, which further finds out the Point of Interest (POI) from either Route Log "L" or Road Networks "G". Based on AESRS architecture, Dummy Data Array (DDA) Algorithm is designed which is more efficient in performance [56] [58].

Based on privacy protection goals discussed in the previous section, we have conducted a critical analysis in this study and compared the different state-of-the-art approaches with TIP attributes in Table I as follows.

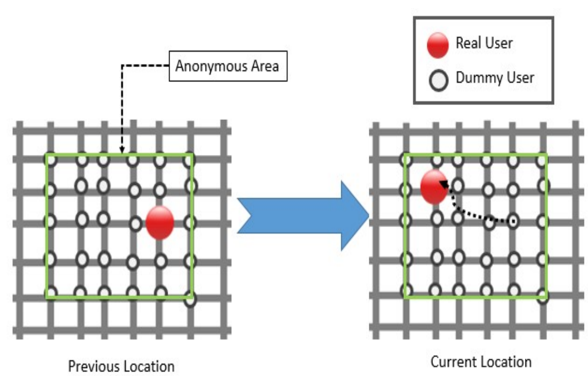


Fig. 8. Dummies on Changing Position.

TABLE I. PRIVACY PROTECTION GOALS IN LBS SYSTEM

Ref. No	Privacy Protection Goals		
	Identity	***Spatial***	***Temporal***
[34]	✓	✓	×
[35]	✓	×	×
[39]	✓	×	×
[40]	✓	✓	×
[41]	✓	✓	×
[42]	✓	✓	×
[43]	✓	✓	×
[44]	✓	✓	×
[46]	✓	✓	×
[47]	✓	✓	×
[48]	✓	✓	×
[48]	×	✓	×
[4]	✓	✓	×
[4]	✓	✓	×

IV. PROPOSED IDP MODEL

This section presents the proposed Improved Dummy Position (IDP) model as shown in Fig. 9, where actual user desire for a point-to-interest to find out the nearby Coffee Shop from his current location using over the road network. Hence, TTP LBS user posted a query to LBS System in order to find out a route path or POI (in our scenario "the nearest Coffee Shop"). Here, the LBS System is Trusted Third Party (TTP). When the user is posting a query, at that time their privacy is at risk. In order to overcome these privacy issues and to keep safe their exact location, the IDP mechanism generates dummy positions in a specific area. This area can be in the form of a grid or a circle. Within one of the defined areas, LBS user posted a request with multiple dummies to TTP LBS for the desired event or Point-of-Interest (POI). This proposed model processes that request, search out the required results from Route Log, if found then return the required requested outcomes to TTP LBS user otherwise invoke Route API for the latest results. By posting multiple queries several times (5-10), an attacker can easily identify the actual user and can take advantage of their information.

In order to overcome this problem, whenever the actual user posted a query to the LBS System their identity will be change. In TTP Based LBS System, the Identity is randomly generated unique ID, provided by an additional resource key Generator. Moreover, to generate indistinguishable dummies, it has used one of the advance methods i.e. Sybil Query to generate multiple false locations that resemble the client actual location. Based on this mechanism, it has achieved our protection goals i.e. provisioning privacy to Time, Identity and Position attributes in TTP Based LBS system. Leading to objectives, a proper environment has provided to the LBS system and the privacy issues between the user and Location Server (LS) thus reduced.

Fig. 9 depict three main components of the IDP system model including LBS client, User Dummy Mixer (UDM), and LBS. These components bring a complete architecture to provide a safe environment for the LBS system. The first and foremost component is LBS client that uses the LBS for nearest places from their current location. An additional resource has provided to the LBS client that generates unique random IDs. Key Generator provides every time a unique ID to TTP LBS user when they send a request to LBS for any POI or desired location. In order to generate several dummies that resemble the LBS client's actual location, Sybil Query has been used for this purpose, as it is the most advanced method to produce fake locations. The second component is User Dummy Mixer (UDM) where mobile users' actual position blend with the number of dummies that are undistinguished.

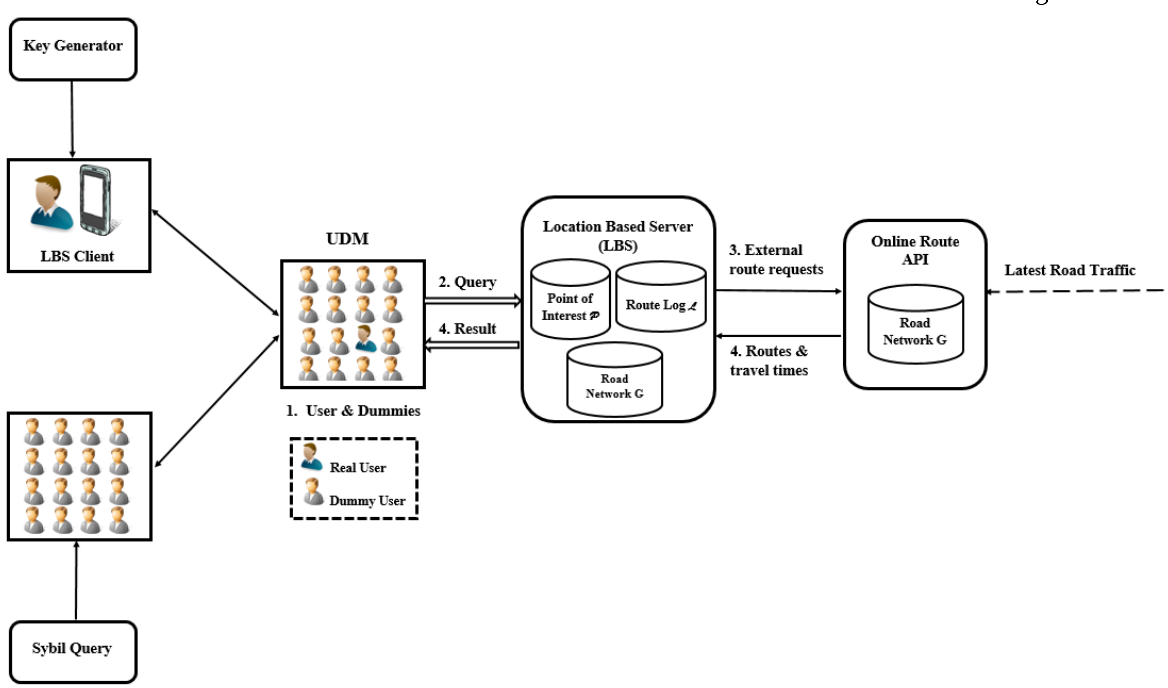


Fig. 9. IDP System Model.

The third and most important component LBS, defined as services accommodate a mobile device location with other information. LBS provides any location-related information according to the desire location that the user has requested to the system. LBS is very useful for users nowadays that it can save a lot of user's time to reach from one location to another. It contains point-of-interest (POI) that users found interest or useful, stores the concurrent POI they have visited frequently. Route log in LBS provide functionalities in the mobile network, which transfer service request such as measuring positions, searching for a route, search to the service provider, search from the service provider based on the user's position. In LBS, the Road network processes the live queries of the mobile user. Online Route API plays a vital role in case if the system does not contain results related to a user's particular request.

A. *Algorithm Design*

Based on the proposed model, we have designed the Improved Dummy Position (IDP) algorithm which is described in Algorithm 1. Note that the same procedure is repeated every time for each user-posted query to TTP Based LBS System. By this algorithm, before sending a request to the LBS system.

- Determine the Anonymity Area A (line 1-3): If the area is grid G, measure the lower limit (L), and upper limit (U), height and width of the distinct space define a grid. To make partition of the grid into the numbers of cells (C) as shown in Fig. 10 L, U coordinates are determined. Each cell Edges (E) and Vertices (V) belong to C, which associated a collection of Edges E, and Vertices V. Vertices are determined besides all cell and one location of the cell given to the user real location.
- In case, the Anonymity Area A is the circle (line 4-5): Angle and radius will measure by respective formulas in order to define an area for user location U(X, Y).
- Set random id provided by the key generator to user location (line 6-8): Assigning the user current location Px, Py to one random cell of gird area G.
- Declare 2-D array DumArr [Nx][Ny], x, y, N, and counter variables i, j (line 9-17): Array consists of a number of N dummies and the index of the user location U(X, Y). A nested while loop is executed to fill the array with dummy positions.
- Add (line 18-19): User current location Px, Py to array and return DumArr[K(x, y) + U(X, Y)].

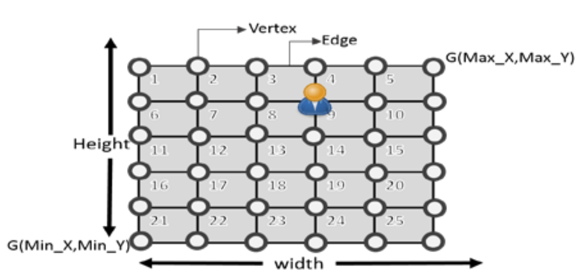


Fig. 10. Grid Partition into Cells.

Algorithm 1: IDP (Improved Dummy Position)

Input: User Location U (X, Y), Anonymous_Area A, Anonymity_Number K, Dummies N, π.
Output: DumArr[K(x,y) + U(X,Y)]
Procedure:
1: If(A==G(L, U)) \\ If area is rectangular than calculate both Height and Width, U,L limit.
2: N ← $\sqrt{G}$ \\ Calculate Number of cells in G
3: (V,E) ∈ N \\ Determine vertices and edges of each cell.
4: Else if (A=Circle(π))
5: $\theta = \frac{2\pi}{k}$; $r = \sqrt{\frac{A}{\pi}}$; \\ Calculate both angle and radius
6: U(X, Y) ← Key Generator \\ Determine actual user key
7: Px ← Random (0, v(N-1))
8: Py= ← Random (0, v(N-1))
9: DumArr[N_x][N_y] \\ Initialize 2-D array
10: i, j, x, y, N \\ Declare variables x-axis, y-axis
11: While (i < N) \\ Fill array with dummy positions
12: **While** (j < N)
13: DumArr[i][j] ← Sybil Query
14: j ++;
15: **end loop**
16: i ++;
17: **end loop**
18: add Px,Py in DumArr
19: Return DumArr

Fig. 11 illustrate the proposed privacy-preserving framework for TTP Based LBS System. According to the given algorithm, it takes U(X, Y), A, N, and π parameters as an input. If the anonymity area is Grid G, calculate Lower and Upper Limit (L, U) otherwise, the defined area will be a circle, measure angle, and radius for anonymity area A. The key generator provides a unique ID to actual user U(X, Y). After this, multiple dummy positions generated by Sybil Query. A 2D array initializes in order to store the dummies N in it. The nested loop has executed until the Dummies N filled in an array. Finally, the query has posted to the TTP LBS; system processes it and returns the point of interest (POI) according to request.

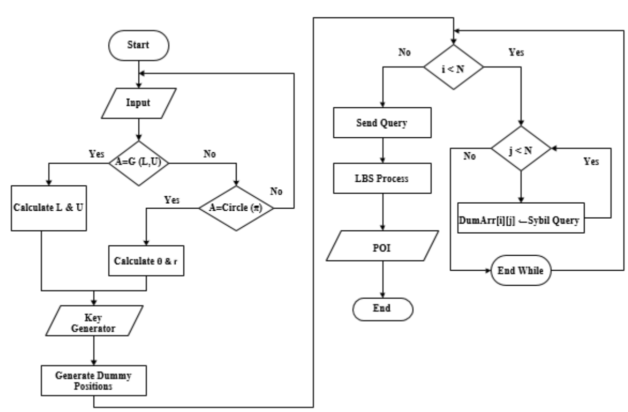


Fig. 11. The Framework of IDP Algorithm.

V. Performance Analysis

In order to evaluate the effectiveness of the proposed Improved Dummy Position (IDP) model, extensive simulation has conducted. In this section, we first describe the simulation environment and present the simulation results. After this, the comparison is performed with Data Dummy Array (DDA) Algorithm.

A. *Simulation Setup*

In this section, we authenticate the performance of the proposed model with the privacy factors. For this purpose, Riverbed Modeler academic edition 17.5 [53] simulation tool was used. Since it could be used for composing complicated network topologies to simulate the sending/receiving message rate. OPNet Modeler was its old name [54].

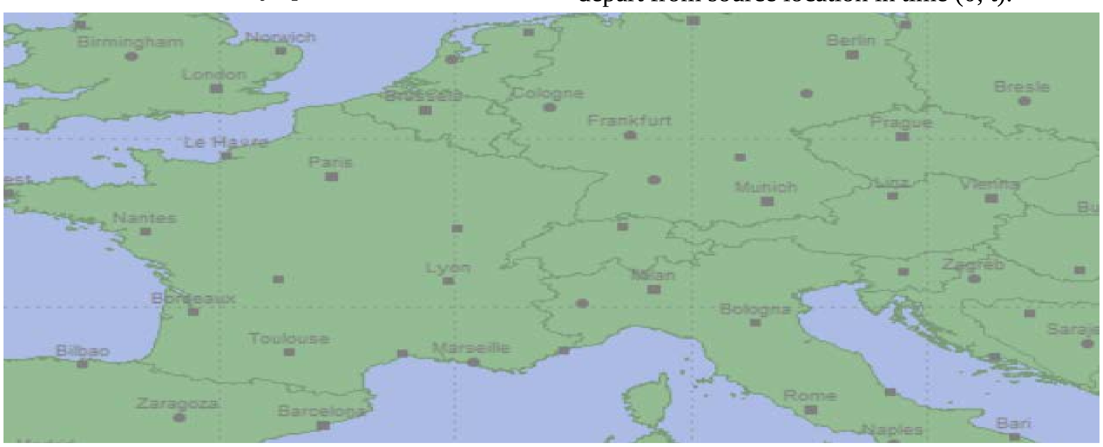
In this simulation, we choose various nodes that represent actual user location from where they want to search out the nearest route path to Coffee Shop in order to preserve personal information of a user along with generated Dummy positions, send to location server over a wireless network. When numerous queries posted to the LBS system and it acknowledges back with a request, the result was evaluated by setting the duration of 1 week. Consider that there is an area A of size 200mx100m. For this simulation, Ethernet and bus topology is constructed. 30 dummy positions/nodes from multiple positions are linked with each other illustrated in Fig. 12(a), (b) and it sends user requests to the TTP LBS system for services. Fig. 13 shows the attributes set during the rapid configuration of bus topology in which value is assigned to a model, delay, and thickness attributes while the rest of the parameters remain default. For nodes, expand the traffic and packet generation arguments where the value of Packet size and Inter arrival Time is modified.

B. *Experimental Results*

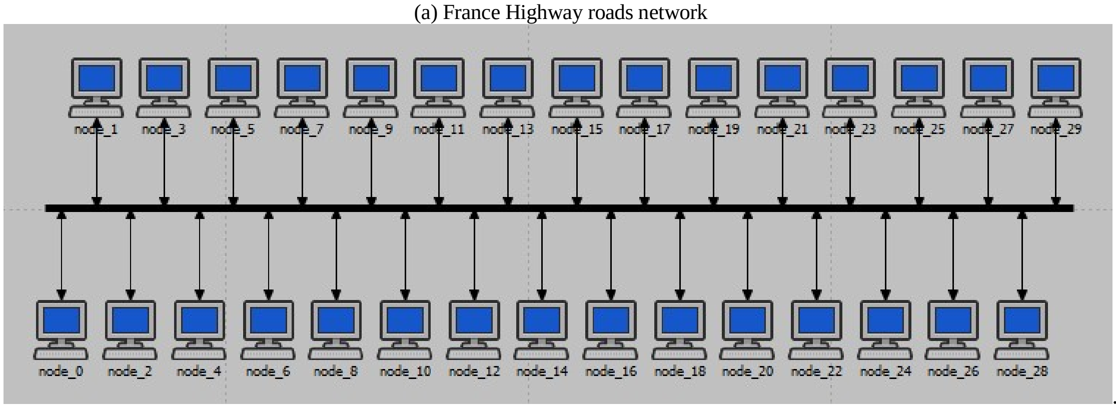
Fig. 14 illuminates the frequency at which LBS receives the data packets which is sent from the Ethernet. We observe that as the time duration increases, the data sending rate (shown in blue line) continual initially but increasing after reaching the maximum. Meanwhile, the query receiving traffic (shown in red line) tends to persistent initially but increasing after reaching the maximum. Further, we observe that it is quite satisfactory for LBS users to take location related services without compromising privacy. The delay in transferring data packets to LBS server were calculated by using “Little’s theorem”.

$$N(t) = A(t) + B(t) \text{ and } t \geq 0 \quad (1)$$

Where A (t) is the number of data packets which are arrived at in time (0, t) and B (t) is the number of data packets that are depart from source location in time (0, t).



(a) France Highway roads network



(b) Simulation Environment

Fig. 12. Riverbed Modeler (OPNet Modeler).

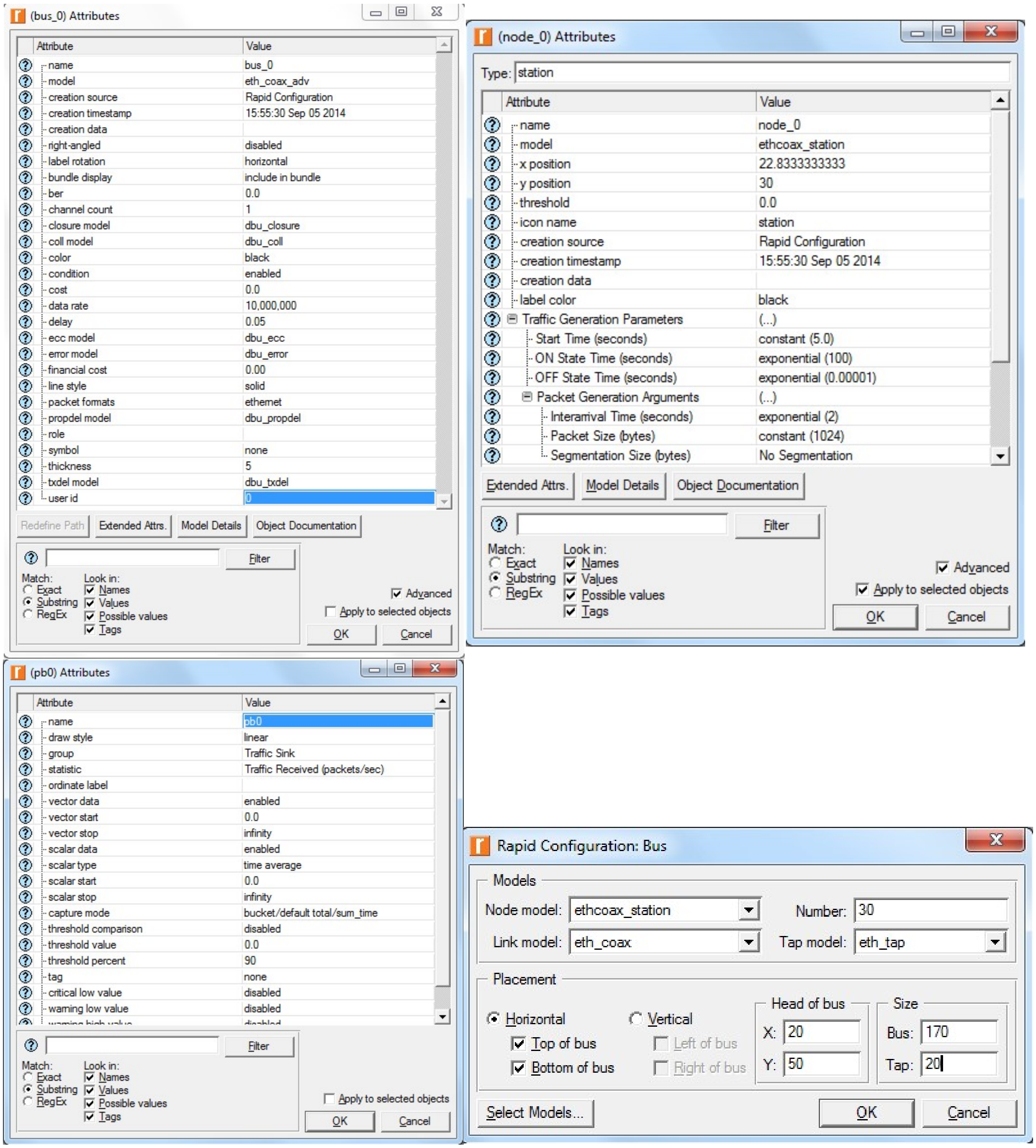


Fig. 13. Configuration of Ethernet Network Nodes.

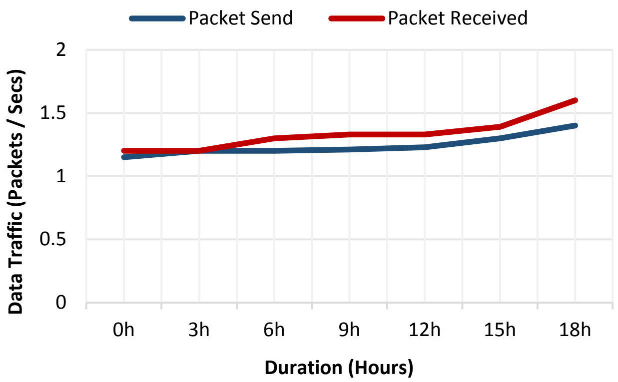


Fig. 14. Data Transferring rate to LBS.

C. Comparative Analysis

In our implementation, we compared the effectiveness of the IDP scheme with DDA concerning different attributes including data transferring rate, Ethernet and Wireless LAN delay, Query success rate, LBS server performance with load, and query processing time, the Route API retransmission attempts and data access rate. These attributes with consequences have been described in the following sections.

1) Measuring data transmission rate: Fig. 15 shows the comparison of the IDP scheme with DDA in terms of data transferring rate. At an initial point, we quantify the data set. When we change the defined dataset, the value of the IDP scheme gradually increases with the increasing time duration, likewise, the value of the DDA scheme also increases with the increasing time duration but its rate is higher than IDP at each defined dataset. it is observed that the data transmission rate of our proposed IDP model is less than DDA. In this case, the frequency at which packets are transferred lower than the DDA scheme. Further, we observed that IDP is better in data transmission as it reduces the collision of data transmission rate significantly.

2) Measuring delay: The delay at Wireless LAN and Ethernet might be the motive of declining LBS server system performance. Fig. 16 shows the comparison between IDP and DDA schemes where delay rate is trivial during query transmission and wireless communication couldn't comprehension to lowering system performance. Fig. 16(a), illustrate that delay in the IDP scheme decreases with less variation as compared to DDA. We also notice, with the increasing time interval both schemes become constant at a certain level. In Fig. 16(b), the change in delay at different time interval in Wireless LAN Delay constitute that IDP delay rate is lesser than the Delay rate in DDA. Hence, the overall delay is decreased.

3) Measuring performance: The fundamental part of the proposed technique was to manage LBS server performance when users posting numerous queries to the system for any POI or any route path to return query results at the server-side. Fig. 17 shows the LBS server performance between the Improved Dummy Position's load processing time and query processing time with the DDA technique. It was also evaluated by [57]. Firstly, the data set is specifying to measure the LBS server performance. The load processing time of LBS server performance in the IDP technique is less than the DDA scheme as shown in Fig. 17(a). On the other hand, the graph of query processing time clearly defines the LBS server takes less processing time in the IDP technique than the DDA scheme as depicted in Fig. 17(b). The performance of IDP is relatively less while the load and query performance time of the DDA scheme is higher and increases gradually.

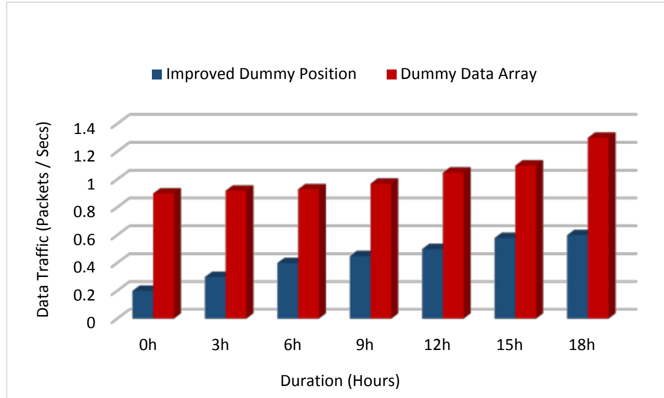
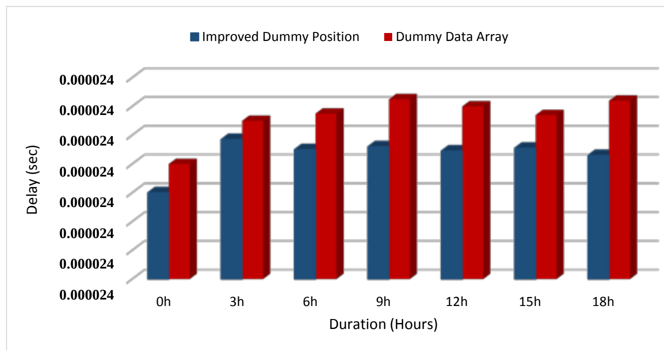
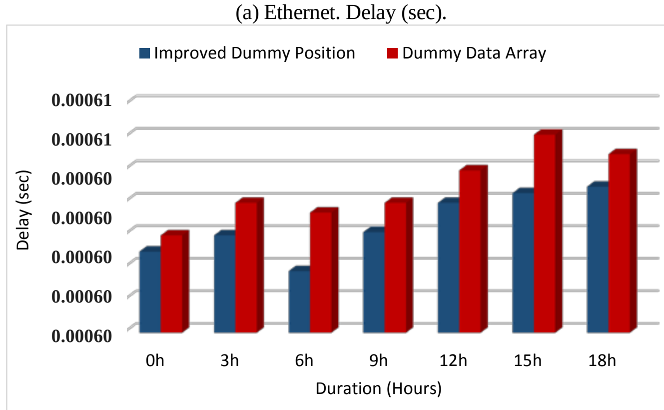


Fig. 15. Comparison on Data Transferring rate to LBS.

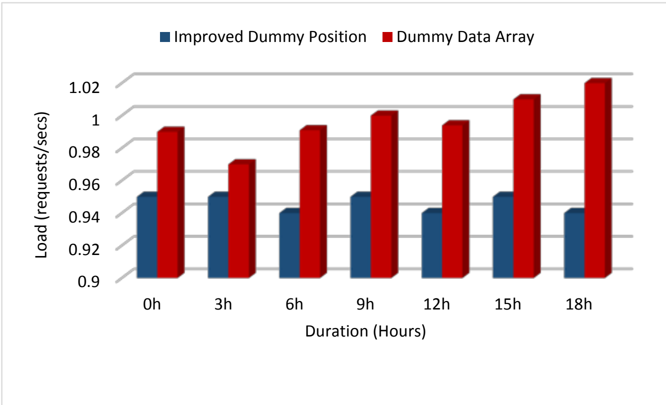


(a) Ethernet. Delay (sec).

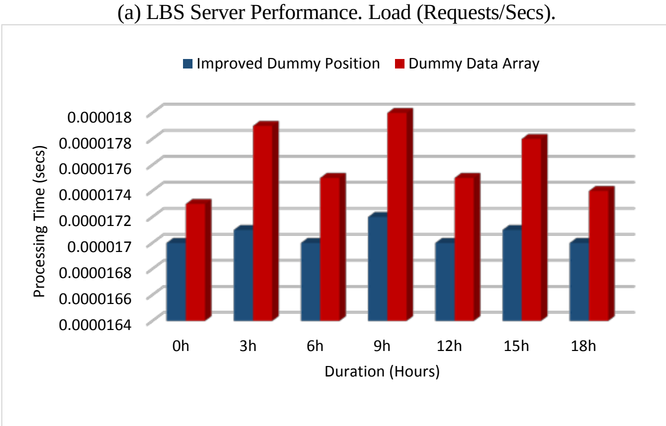


(b) Wireless LAN. Delay (sec).

Fig. 16. Delay in Ethernet and Wireless LAN.

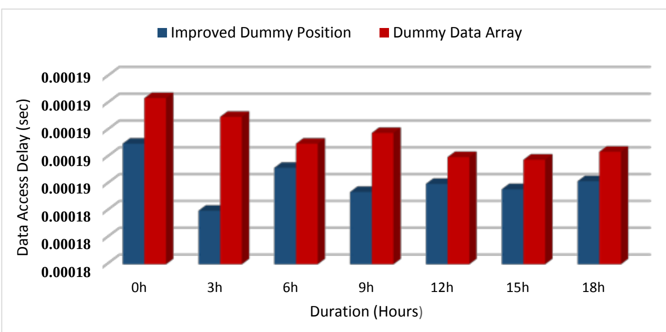


(a) LBS Server Performance. Load (Requests/Secs).

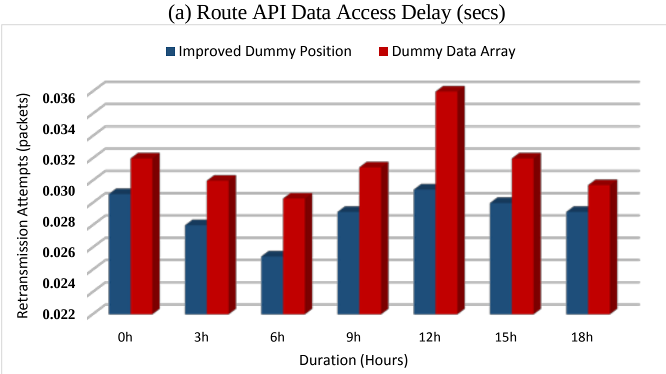


(b) LBS Server Performance. Query Processing Time (secs).

Fig. 17. Performance Comparison: LBS Server.



(a) Route API Data Access Delay (secs)



(b) Route API Retransmission Attempts (secs)

Fig. 18. Route API Retransmission Attempts and Data Access Rate.

4) Measuring data access delay and retransmission Attempts: Fig. 18 demonstrates the determination of data access delay through route API [55] and Route API retransmission between Improved Dummy Position and Data Dummy Array schemes. In Fig. 18(a) data access delay of our IDP approach is far better than the existing DDA technique as a tremendous decrease in delay raises when the duration gradually increases. In Fig. 18(b) Route API retransmission of packets is lower than DDA because, an IDP, the LBS server first recognizes the identified path against any packet sent by the TTP LBS user, then provide the accurate local path or point-of-interest (POI).

VI. Discussion

LBS are real-time geographical data from a handheld device that depends on mobile user location to provide information or service. These services allow LBS users to find out required and nearest places such as banks, educational institutions, restaurants, coffee shops, shopping areas, stores, airports, hospitals, cinemas, concerts, and other places or events. Nowadays, the usage of LBS has been increased due to advancements in mobile technology as it requires the geographic location of a mobile user. This leads to serious privacy concerns, as mobile user privacy is at risk. An attacker can take advantage of mobile users' personal information thus the user has to face problems.

In the current study, we highlighted three privacy attributes, user identity, spatial information (position), and temporal information, which need to be protected in order to provide privacy to the LBS user. The privacy of user identity means that a malicious party has access to a location database that contains the actual location of each user but is unable to infer the information about the user from the record because the user is hidden from these untrusted parties. The privacy of the LBS user time of the query is to conceal the temporal information of the user from an attacker so that from time factor actual location of the user could not be disclosed.

An LBS system can be utilized in three ways to provide privacy: Trusted Third Party (TTP), Non-Trusted Third Party (NTTP), and mobile Peer-to-peer networks (P2P). The current study deals with the TTP model where the third party is any server that is assisting LBS to protect the user's private information from disclosure. In TTP LBS System, several privacy provisioning approaches have been recently proposed that are protecting mobile user locations in their way. The main approaches that are ensuring user identity and spatial information are Location Clocking, k-anonymity, Dummy Position, Mix Zone, Policy-based Scheme, Pseudonymisers but the protection of temporal information also required in order to provide full privacy to TTP LBS user. Although all these approaches serve, a great deal for preserving users' privacy still these approaches do not cover all required attributes (Time, Identity, and Position).

To address the privacy challenge under defined metrics, a novel privacy-preserving approach was required. In terms of study objectives, we have conducted a critical analysis of all TTP based approaches and proposed a new model named

Improved Dummy Position "IDP". Leading to objective, we enhanced the dummy position and proposed IDP model that ensures user privacy by changing the user id every time they posted a query to TTP Based LBS System. Based on this model, we design an Improved Dummy Position (IDP) algorithm that takes input user location, anonymity area, and the number of dummies. Anonymity area of user can be grid or circle. The ID has been provided by an additional resource that is a key generator and Sybil Query generates dummies. It returns an array that contains user location and dummies that are indistinguishable. Based on the algorithm, a framework is a design that defines the proper flow of the algorithm.

Further to investigate the privacy rate in the proposed solution, we quantified different privacy attributes through the simulation tool Riverbed Modeller academic edition 17.5. A scenario was created where the size of region A is 200m x 100m. We used Ethernet for simulation and bus topology is constructed consisting of 30 dummy positions/nodes from multiple positions linked with each other and it sends user requests to the LBS system for services. We measured the data transferring rate of the packet sent and received by the LBS server from Ethernet. The consequences showed that the proposed IDP model outperformed the existing state-of-the-art privacy protection techniques by all measured attributes.

Further, we evaluated the IDP model by conducting a comparative analysis with existing models discussed in the literature. In our experiments, we measured delay, performance of LBS server, retransmission, and data access rate. It was observed that IDP brought a tremendous improvement in our results as the success rate of the packet sent and received, improved performance of the LBS server in terms of load and query processing time. The delay in Ethernet and wireless WLAN is less and the retransmission rate of Route API is relatively low. However, IDP results showed that the proposed solution is more efficient than the Data Dummy Array (DDA) algorithm of AES-RS architecture based on measured parameters.

Therefore, the proposed model provides full privacy to TTP LBS user's three attributes (Time, Identity, and Position) and provides a secure environment for getting services from the LBS system. LBS user personal information is released from the service provider and this puts their privacy at risk but relying on the TTP LBS System where anonymised is used to store actual user personal information and protects information from disclosure. Now, the Mobile user fully depends on the TTP Based LBS System without the concern of information exposure.

VII. Conclusion

LBS plays a vital role in emerging mobile computing systems. Leading to TTP based LBS systems, the mobile user is facing some substantial challenges, and privacy is one of these. Fundamentally, a mobile user's privacy is concerned with the user's identity, spatial information, and temporal information. Leading to these privacy attributes, the current study addressed the privacy challenge by proposing a new privacy protection model named "Improved Dummy Position" (IDP) which is the improved version of the dummy position mechanism. In order to make sure the privacy authenticity, we implemented IDP in real France highway road networks using Riverbed modeller academic edition 17.5 simulation tool and measured different privacy factors including Ethernet delay, Query success rate, system performance (load and query processing time), route API retransmission and data access rate. It was observed that IDP outperformed the existing state-of-the-art models and achieved 80% privacy by improving the rate up to 30%. However, this significant improvement provided complete protection in all metrics. From a future perspective, it is crucial to raise the user's focus towards the importance of location privacy and the imperilment when disclosing one's location to third parties. Also, it is required to test the proposed model with real clients with real locations in a real environment with a large system in order to make our contributions stronger.

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Survey on Homomorphic Encryption and Address of New Trend

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***Abstract*—Encryption is the process of disguising text to ensure the confidentiality of data transmitted from one party to another. Homomorphic encryption is one of the most important encryption-related processes which allows performing operation over encrypted data. Using different public key algorithms, homomorphic encryption can be implemented in any scheme. There are many encryption algorithms to secure operations and data storage, which after calculations can obtain the same results. While there is a considerable contribution and enhancement in the field of homomorphic encryption for various performance metrics, there is still an necessity to clarify the applications dealing with this technology. Recently, many distinguished research papers have been filed to address the need for various applications of homomorphic encryption. Recently, many distinguished research papers have been filed to address the need for various applications of homomorphic encryption. Example of these applications but not limited to : Vehicle to Vehicle (v2v) secure communication, cloud security, Vehicular ad-hoc networks (VANET), Blockchain, E-Voting, Data mining with privacy preserving and healthcare sector. This article aims to introduce a literature survey to close the gap in homomorphic encryption systems and their applications in the protection of privacy. We focus on above-mentioned applications and present our recommendations for future work.**

Keywords*—Homomorphic encryption; cloud computing; V2V; VANET; blockchain

I. Introduction

Over one billion devices are connected to the Internet and this number will continue to grow. Security is of the utmost importance especially since the Internet is being used for data storage. The purpose of encryption is to hide information from unauthorized parties and to ensure both the confidentiality and integrity of date. Data can be stored in an encrypted format; however, it must be decrypted before being processed. This can make the data vulnerable and susceptible to attack. Recently, modern cryptology has been able to directly compute encrypted date similar to computations on plaintext using homomorphic encryption (HE). Homomorphic stems from the ancient Greek (homos) meaning "the same" and (morphe) meaning "shape". Homomorphic encryption allows direct computing or processing of data without the need of decryption while enabling one to perform operation on the already encrypted data without knowing anything about it's real value. The homomorphic encryption used in untrusted third parties provides privacy and security for data processing and it offers effective data protection and solves important privacy issues. The concept of HE can be explained metaphorically by using the jewelery shop example: Alice owns the jewelery shop and she does not trust her workers with her jewelery, so, she gets an impenetrable box, hands it off to someone only by using special gloves, and she is the only one who locks it. When Alice wants to make a new piece of jewelery, she locks the materials inside the box. The employees can work on the material inside the box but cannot get it out. Once the work is finished, Alice opens the box with her key and takes out the finished jewelry. This way, the workers produce the jewelery from raw materials without every truly accessing it themselves. In terms of homomorphic encryption, HE is the impenetrable box and the key to the jewelery box is like ciphering the data. The gems represent the data or plaintext and is processed via special gloves without every getting access to the initial data.The final product, such as a ring,represent the initial data.From a historical perspective, the concept of HE was first proposed in 1978 by Rivest, Ronald L., Len Adleman, and Michael L. Dertouzos [1]. Craig Gentry's in 2009 constructed in Ph.D. thesis the first fully homomorphic encryption (FHE) scheme [2]. In 2010,Smart and Vercauteren presented optimization in FHE scheme with smaller chiphertext and key[3]. The remainder of this paper consists of surveying the homomorphic encryption is Section 2, the classification of HE in Section 3, and discusses the homomorphic application is Section 4.

II. Related Work

Homomorphic encryption has been reviewed by [4], [5] earlier. Recently, authors in [6] reviews the state-of-art techniques for incorporating Homomorphic encryption in cloud security. They highlights Homomorphic challenges and limitations for applying HE methods on encrypted data for cloud. Authors in [7] details the required background and related knowledge of HE schemes. Authors in [8] presents an overview of how HE can be utilized for Big data computations. They point out related challenges, opportunities and future enhancements. In [9] summarized the fully homographic encryption properties, applications and techniques. HE libraries were reviewed by [10] as well as an overview of all supporting languages of these libraries. Moreover, the study mentioned the potential applications used by such libraries. Authors in [11] presented a systematic review for HE and illustrates current demand applications and future prospective including security and privacy. In this survey we highlight more potential application which has not been covered by abovementioned reviews.

III. Operation on Homomorphic Encryption

HE is used to perform operations on encrypted data without decrypting it. The client is the only holder of the secret key. After decryption, the result of any operation is the same as if it was calculation on raw data.

A. Addictive

Encryption schema is called addictive Homomorphic Encryption if

$$E(m_1 + m_2) = E(m_1) + E(m_2) \quad \forall m_1, m_2 \in M$$

Where E is encryption algorithm, M is set of all possible massage and without knowing m_1 or m_2.

B. Multiplicative

Encryption schema is called multiplicative Homomorphic Encryption if

$$E(m_1 * m_2) = E(m_1) * E(m_2) \quad \forall m_1, m_2 \in M$$

Where E is encryption algorithm, M is set of all possible massage and without knowing $m_1 \text{or} m_2$. For notation in HE it only allows addition and multiplication operations functionally complete set. For any Boolean circuit can design only via XOR gate performs the addition and AND gate performs the multiplication.

IV. Classification of Homomorphic Encryption

A. Partially Homomorphic Encryption (PHE) Schemas

PHE was first attested use of homomorphic encryption introduce by Rivest in 1976.but it was called "privacy homomorphism" [1]. PHE which allows performing single operation either addition or multiplication 'n' number of times on encrypted data, that mean which allows any type of operation without any limitation. There are several algorithms well-knowing for PHE [12] such as:

1) RSA Algorithm (1976):

- Key Generation:
  Step 1: select p and q primes random numbers.
  Step 2: calculate $n = p.q$ and $\phi(n) = (p-1)(q-1)$.
  Step 3: select e such that $gcd(e, \phi(n)) = 1$.
  Step 4: determine d such that $e.d \equiv 1 mod \phi(n)$.
  Step 5: the public key $pk = (e, n)$ and secret key is $sk = (d)$
- Encryption:
  Compute $c = E(m) = m^e(\mod n)$
- Decryption:
  Compute $m = D(E) = c^d(\mod n)$
- Homomorphic Property:
  The homomorphic property of RSA shows following $E(m_1 * m_2)$ directly without ever decrypting it. The RSA is only support homomorphic over multiplicative, it does not support homomorphic over addictive of chiphertexts. Suppose $m_1, m_2 \in M E(m_1) * E(m_2) = [m_1^e(\mod n)] * [m_2^e(\mod n)] = (m_1 * m_2)^e(\mod n) = E(m_1 * m_2)$

2) Elgamal Algorithm (1985):

- Key Generation:
  Step 1: create an efficient cyclic group 'G' of order 'q' with generator 'g'.
  Step 2: choose a random value $x \in \{1, 2, \ldots q-1\}$.
  Step 3: compute $h = g^x$.
  Step 4: the public key is$pk = (G, h, q, g)$ and x as private key.
- Encryption:
  Step 1: chose random number$r \in \{1, 2, \ldots q-1\}$.
  Step 2: compute $c_1 = g^r$and calculate the shared secret key is $S = h^r$.
  Step 3: convert the secret massage m into $m' \in G$.
  Step 4: calculate $c_2 = m' * S$
  Step 5: the ciphertext pair are $c = E(m) = (c_1, c_2) = (g^r, m' * h^r) = (g^r, m' * (g^{x^r})$
- Decryption:
  Step 1: compute shared secret key $s = c_1^x$where x is secret key
  Step 2:$D(E) = c_2.s^{-1} = mg^{xr}.g^{-xr} = m$
- Homomorphic Property:
  $E(m_1) * E(m_2) = (g^{r_1}, m_1'.h^{r_1}) * (g^{r_2}, m_2'.h^{r_2})$= $g^{r_1+r_2}, m_1' * m_2' h^{r_1+r_2}) = E(m_1 * m_2)$

3) Pallier Cryptosystem (1999):

- Key Generation:
  Step 1: choose p and q prime random number equal length such that $gcd(pq, (p-1)(q-1)) = 1$
  Step 2: compute $n = pq$ and $\lambda = lcm(p-1, q-1)$ the lcm means Least Common Multiple
  Step 3: choose integer random $g \in Z^*$ such that $gcd(L(g^\lambda mod n^2), n) = 1$ with L function define as follow $L(u) = (u-1)/n$
  Step 4: the public key $pk = (n, g)$ and secret key is $sk = (p, q)$
- Encryption:
  Step 1: select random number $r \in Z^*$
  Step 2: compute $c = E(m) = g^m r^n(\mod n^2)$
- Decryption:
  Compute $m = D(E) = (L(c^\lambda(mod n^2))/(L(g^\lambda(mod n^2))$
- Homomorphic Property:
  $E(m_1) * E(m_2) = [g^(m_1) r_1^n(mod n^2)] * [g^(m_2) r_2^n(mod n^2)] = g^(m_1 + m_2)(r_1 + r_2)^n(mod n^2) = E(m_1 + m_2)$

B. Somewhat Homomorphic Encryption (SWHE) Schemas

SWHE allows performing different operations with limited number of times. There are several SWHE well known examples such as BGN encryption scheme which was the first practical SWHE developed by Beneh-Goh-Nissim BNG Algorithm (2005)

C. Fully Homomorphic Encryption (FHE) Schemas

FHE combines the advantage of PHE with SWHE, which allows to perform unlimited amount of operation for unlimited

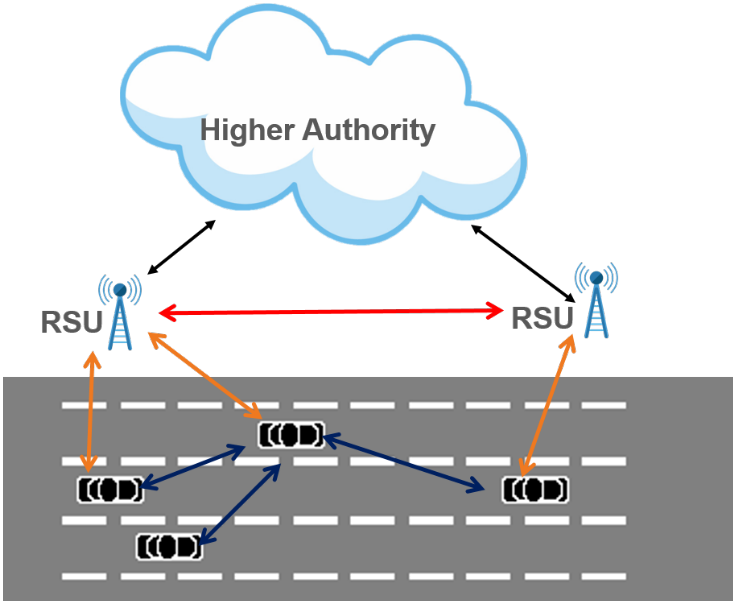

Fig. 1. VANET Communication

number of times. FHE was first practically proposed by Craig Gentry in 2009.

V. Applications of Homomorphic Encryption

A. Vehicle Communication

Among the things right now in the world of technology is a change in the way out the machines that we use interact it. It used to be that the machines we use were just thinks where a button is pushed and something would happen, but now they have progressed to be able to interact with themselves. Imagine a future where vehicles are able to communicate with each other that are known as Vehicle to Vehicle (V2V) technology. V2V provides drivers with warning of potential crash to avoid 60 percent of road accidents according to some statistics. The V2V, also known as Vehicular Ad-hoc NETworks (VANET) technology, uses vehicles as nodes in network [13]. Each vehicle node is equipped with WAVE IEEE 802.11p standard protocol [14], On-board side units (OBDs),the road static infrastructure units called Road Side Unit (RSU)[14] [15]. The three types of vehicular networks most used are Vehicle to Vehicle (V2V), RSU to RSU (I2I) and Vehicle to RSU (V2I). The vehicular network based on wireless protocol is called Dedicated Short Range Communications (DSRC) protocol. The fundamental VANET network scenario is shown below in Fig. 1.

1) VANET applications: are not limited to avoiding road accidents and traffic congestion notifications. The VANET applications are classified according to their purpose

- Safety Applications reduce road accidents and aim to make it easy for helping the driver in specific situations, such as detecting traffic congestion and warning of potential traffic jams. They enhance road safety via such things as collision avoidance by providing emergency alerts in up-to half a second before a crash occurs, which would lead to an avoidance of up-to 60 percent of accidents. Also the vehicle will cooperate by exchanging messages for slow/stopped/post-crash-notification to other vehicles to avoid potential accidents.
- Commercial Applications The main aim of commercial applications is to provide value added services entertainment as web access, travel guidance show the detail location of the nearest restaurant and petrol station, streaming audio and video, and can even provide weather information.

2) Entities in VANETs Security:

- The driver: Responsible for movement of vehicle by making vital decisions and is the most important part of VANET safety chine.
- The vehicle (OBUs): Includes all type of vehicle like cars, bus or truck. The vehicle or nodes in VANET network provide two kinds of normal vehicles that exist in network nodes and the malicious vehicle created by an attacker.
- The infrastructure: It includes RSU which operates in normal way and malicious infrastructure node maybe act as RSU terminal.
- The third party: It includes all direct stakeholders for the system, it may be trusted or semi-trusted third parties. Third party refers to traffic police, the transport regulator, vehicle manufactures and judges. The HE is used to encrypt data so to not be visible for third party but able to process it.
- The attackers: The attacker wants to smash security of normal vehicles to achieve a goal. And it includes external attackers or internal attackers such as authorized vehicles of network VANET.

3) VANETs Security:

- Vehicle privacy: The location of the vehicles should be ensured as much as possible preventing other entities [16]. If the vehicle route leaked, the attacker can trace vehicles which affects driver's safety and privacy.
- Third parties: While third party might needs process the data of entity, it should be secured from malicious usages.
- Authentications: authentication must be supported in VANETs because entities cannot detect if a received massages is normal or malicious [17]. In addition the received data must be consistent with latest data version.
- Real-time availability: Due to a high request of vehicles in the network, it needs to be able to react in real time to various events [18]. And it necessary to have other forms of communication even in the presence of strong communication channels to react with denial of service attacks.

B. Cloud Computing

Before cloud computing, traditional business applications were very complicated. It required a variety amount of tools, hardware, and software and needed an entire team of IT experts to install, update, and maintain them. The "outsourcing" and "server hosting" different names already existed under the cloud computing but the poor performance of processors used, expensive costs of the materials used and slowed internet connections. However the recent advances in technology paved the way for operations with faster processing. The Cloud Computing in simple terms is the offering applications of IT services which are provided by a third party hosted on the internet [19]. The most common service models in cloud computing which are defined in the NIST document Platform as a Service (PaaS) provide a client hosts the hardware and software on its own infrastructure and usually needed for application development over the internet. The user can focus on creating running applications and data sets, Infrastructure as a Service (IaaS) a cloud provider hosts the infrastructure include servers, storage and networking hardware. Software as a Service (SaaS) means delivering software to multiple clients on-demand over the internet. The first priority for researchers is the security challenges and the issue for organizations is to consider moving to the cloud which is the biggest concern.

The security concerns: can be categorized into data security, third party control and finally privacy and legal issues.

- Data security, this is the risk created from losing physical, personal and logical control of data . Such as launching attacks across tenant accounts and also for data remembrance remains as issue due to the replication and distribution of data even after a user has left a cloud provider[20].
- Third-party control, this is the most prime cause of concern for security in the cloud [20]. Third party access to the value of corporate information can lead to a potential loss of intellectual property by enabling a service provider company malicious insider who accesses rights to secret corporate information.
- Privacy and legal issues, data in the cloud is usually globally distributed which raises concerns about data exposure and privacy.

1) Using Homomorphic Encryption in cloud computing: To solve issues in security concerns requires that data stored in the cloud provider are encrypted [21] . However, the client (user) would not be able to use the cloud power to compute outsourcing data because the data would be in an encrypted from. The cloud provider needs to decrypt it to execute the required calculations which affect the data privacy and confidentiality, to perform the computation in encrypted data without ever needing decryption of homomorphic encryption. Since the client is the only holder of the secret key, the result of any operation, it is same as the used in actual data.

C. Signal Processing

A "signal" describes how some physical quantity varies over time or space. Signals can be any function of space or time (sounds waves, images). "Signal Processing" is manipulating a signal to change its characteristics or extract information. Signal processing algorithms can be offloading the computations and computationally intensive to a computationally powerful server may be essential. However, the problem is to perform secure computations of a signal-processing algorithm so that the server does not know the data and does not know the algorithm used if possible.

1) Recent advances in homomorphic encryption:

- In [22] authors suggested ways to solve the privacy related issues through homomorphic encryption. **Paillier's** (1978 to 2008) published several homomorphic encryption schemes to process encrypted data at the same time with only one type of operator. The first broken FHE scheme has been proposed by Gentry in 2009, which is involved with cryptosystems to process both multiplications and additions in the encrypted domain.
- Processing signals in the encrypted domain is a significant challenge. Recently, a lot of researchers achieved specific tailored solutions concerned with many applications. FHE scheme Construction requires the management of the remaining random part called noise to ensure decryption by keeping it below a certain limit. Bootstrapping is the first way to solve this noise problem and was used in Gentry's first FHE scheme.
- Authors in [22] concluded that The Brakerski-Gentry-Vaikuntanathan (BGV) is an asymmetric bits encryption scheme. It is based on lattices, like most FHE schemes. the cryptosystem divided into two versions: first, dealing with integer and second one with integer polynomials [the security associated with ring-learning hardness with errors.
- Homomorphic operations affect times that we need to call the functions Rescale and SwitchKey. Working with FHE schemes hinders us in higher-level programming terms to programs or algorithms that have input limits and a control flow that is independent of encrypted data.
- An experimental study was conducted with an Intel dual core 2 GHz processor on a laptop, using the aforementioned parallel depth cache and SwitchKey. It was found that despite the reality that cryptosystems in the BGV style offer very powerful theoretical safety characteristics, practical parameter setting for both the BGV scheme and its brothers is an issue that still requires further theoretical studies. These numbers are representative as one of the first applications of a fully homomorphic cryptosystem was acquired.

Finally, several measures have been taken to bridge the divide between non-trivial algorithms and their practical, comparatively seamless, FHE systems execution. We can perform easy algorithms on BGV-style cryptosystems homomorphically in a sensible moment in the future. Nevertheless, we have shown that the performance achieved is still far from allowing more computationally engaged algorithms to be executed at a non-prohibitive time. Nevertheless, there is hope that theoretical progress has been fast since 2009 and that study is only just starting on the "FHE-friendlyness" algorithm, compilation, as well as ad hoc optimized execution, allows for these cryptosystems. As we have suggested in this paper, these latter areas of study can be anticipated to add considerably to the efficiency changes needed to render homomomorphic encryption-based computations, especially in the signal processing sector, are a practical reality.

2) Secure signal processing in the cloud: In [23] authors presented some challenges that multimedia clouds tackle to be fully operational. Cloud services can be introduced in feature of infrastructure, platform as a service and software as a service. There are three types of signal processing apps that highlight the cloud's privacy issue: outsourced biometric identification, e-health, and outsourced adaptive or cooperative filtering. Attaining differential privacy arises at the service provider's expense of a decreased utility as the calculation results are degraded by noise. For cloud applications, this should be evaluated and regarded. In a cloud situation, many signal processing in the encrypted domain (SPED) problems must be faced in order to improve effective privacy-preserving alternatives. Coordination should therefore be improved in the following dimensions: level of privacy, precision, computing load and communication. These freedoms materialize in the technological need for a generic non-interactive alternative for the outsourcing of personal processes, for which cloud computing is a paradigm situation and poses actual difficulties. Defining and quantifying privacy in the cloud is the first and most important problem. There is a wide variety of cloud applications, from very simple spreadsheet apps to synthetic image images rendering. The design of effective FHE that enables the practical use of non-interactive homomorphic processing is the primary region of studies that can contribute to viable alternatives such as the effective personal execution of nonlinear tasks, the effective mixture of outputs from various clients.

3) Smart metering systems: In [24] authors illustrated that smart grids have ongoing spread in many countries but it has many challenges as related to technology and business. Signal processing has important challenges as complex utility function, accuracy loss and also private smart meter measurements, however core smart grid function remain intact.Secure signal processing (SSP) is established to prevent the access of private data by untrustworthy entities as utility providers, while enhancing it as a tool to process the smart meter measurements. The distributed setting of the smart meters and its functions in maintaining privacy with hardware constraints constitute a problem domain for the signal processing research community, it benefits from distributed computing experiences, optimization and accurate communication. Regarding privacy protection, researchers recommended that most studies had to invest in cryptography, getting familiar with its utility and limitations.

4) Biometric Identification: In [25] authors represented the application of techniques of secure two-party computation to biometric identification. This enables computing biometric identification algorithms while protecting the privacy of the biometric data. Many secure computation techniques include biometrics including oblivious transfers, garbled circuits, and garbling a circuit. The impact of using secure multiparty computing techniques on biometric identification systems ' computational costs highlights the system's biometric accuracy. In biometric identification systems, simplified versions of the encoding and matching algorithms are also deployed. These simplifications enhance cost reduction, but they also at the same time decrease accuracy. It includes various techniques as iris and fingerprint. As far as fingerprints are concerned, the minute depiction and advanced range measurements result in more outcomes that are accurate. However, for secure multiparty computation (SMC) methods, neither the depiction nor the corresponding algorithms are suitable. Using streamlined depictions with set size and easy measurements, such as Euclidean distance finger code or Hamming distance binary feature maps, improve privacy at a reasonable computational cost at a slightly less accurate price. These binarization methods are also used as blurred engagement for other methods of privacy preservation.

5) Neighbor methods: In [26] authors discussed three classes of privacy-preserving NN (PPNN) methods, illustrating the building blocks as distance computation and minimum finding that can be realized under privacy constrain .It also addressed secure computation for a wider public of signal processing, new theoretical and applied intersection work on signal processing, cryptography and theory of information. Many studies have been made to carry out the fundamental thoughts and primitive activities that make up PPNN search's construction blocks. Signals for processing were used as outputs for PPNN protocols. Signal processing techniques like press fingerprinting and solid hashing often provide privacy on their own, complementing the PPNN protocol. In safe multiparty computing, several intriguing open issues immediately affect the privacy, velocity, complexity, and versatility of PPNN techniques. Progress in doubly homomorphic encryption is particularly useful in the category of cryptographic methods. Specifically, if the text size and the complexity of the encryption and decryption operations can be managed, it would then be possible to encrypt your data and send it to a cloud-based server that returns a single round of PPNN results. There would be no need for intermediate return and decryption of cipher documents in such a truly outsourced computation configuration, so PPNN protocols would be significantly simplified. Many classic collusions or malicious assault privacy guarantees apply only to information-theoretical techniques computing with more than three sides.

D. HealthCare

- Health care systems run in an environment where sensitive data, must hide from external entities. Over the last few years, e-health records have become more spread. A digital record makes it more reliable and easier to access by different medical facilities.
- Analysts need access to medical records to compute some parts of records so they can access them by HE which supports the sharing of information for healthcare applications. It allows such access without sharing full records in the clear, so we avoid the

violations without disrupting the critical applications. HE protects patient and pharmacy privacy by evaluating the treatment process to obtain safe and effective treatment.

- Homomorphic encryption (HE) offers a tool to protect sensitive data, which can solve the problem of privacy worry. Before sending it to the cloud, the clients are given the chance of encrypting their sensitive information. The cloud will then calculate their encrypted data without the need for the decryption key. HE can be used to the encrypt the data measured by portable medical devices by uploading them on the cloud and making them ready to be used by the authorized user.
- Homomorphic encryption allows computing queries over encrypted data, and returns an encrypted answer to the analyst. The analyst then decrypts the answer on a trusted platform. No one know anything about the data or the results of such queries.
- To preserve the patients privacy information and confidentiality and confidentiality and to use fully homomorphic encryption, the Cloud Computing Platform will only conduct operations using encoded data and provide recipients with the results. No information can therefore be revealed during the communication stage [27].

1) HE applications in Genomics:

- Sharing data with privacy is the most critical point in genomics range; it contains sensitive signals (DNA, magnetic resonance images).
- The immediate development of genome sequencing technology allowing accessing of genome datasets may cause high risks for personal privacy. Using homomorphic encryption to solve this problem so that all the computations can be performed in an untrusted cloud without requiring the decryption key saves the privacy of genome data.
- Fully Homomorphic Encryption (FHE) allow encrypted data to be computed directly in the cloud without the need to bring the data back to the computational.
- The use of HE-Cloud based would be highly beneficial for e-health allowing the uploading of different genomic datasets to the cloud while providing precision medicine and therefore improving the health of patients.

E. Electronic Voting

- Electronic voting (known as e-voting) is a form of decision making that uses electronic means, and the voters make their choices by the aid of a computer to take care of casting and counting votes.
- E-voting has many benefits when compared to traditional voting. Some of these benefits are the faster calculations of results, efficiency, reduce costs, supports different languages, and has a lower chance of human risk and mechanical errors.
- Several e-Voting schemes support the tallying process using the bulletin board (BB). During the vote tallying process each voter gets a receipt that includes some information in encoded form. After the voting closes all encoded votes are published on BB, and each voter can verify that own votes have been recorded as cast using the receipt.
- The purpose of electronic voting is to provide several elaborated characteristics. An e-voting protocol should guarantee privacy to avoid anyone recalling a specific user's ballot, and variance to enable each elector to check that their ballot occurs in the bulletin board and to guarantee that the initial count of ballots applies to legitimate electors' ballots.

1) Secure E-voting using Homomorphic Technology:

- Nowadays, voting is one of the most important activities. The encryption techniques facilitate the implementation of electronic voting. They propose a secure protocol for electronic voting which is suitable for huge votes. The scheme based on Homomorphic Technology is simple, the procedures are transparent, and can be implemented in a practical environment. It allows a voter to exchange untraceable authentic messages, and it uses anonymous channels. The scheme ensures privacy, verifiability and efficiency.
- The structure of the proposed protocol is divided into three phases; the set up phase, in which the parameters are set the voters' registration, the voting phase which is the core of the procedure in which the ballot produced by the voter is processed and finally, the tallying phase in which the result is decrypted [28].
- HE raised as a new solution for e-voting systems. FHE used to design and implement an e-voting system, and it used to provide both operations additive and multiplication.
- New Efficient Multiplicative Homomorphic E-Voting scheme is designed to overcome the disadvantage of the existing schemes. It uses the ElGamal encryption algorithm with distributed decryption. In addition, it uses an efficient and verification mechanism to achieve efficient vote. It employed a grouped tallying mechanism to prevent overflow of votes, while shuffling of groups is used to control the privacy of tallying.

2) E-voting using cloud services:

- The suggested e-voting scheme is comprised of parts, voting servers, authentication servers, newsletters and electors. The distinction between the polling server and the authentication server makes it possible to receive the voting server in any data center service or cloud service provider.
- This scheme offers more privacy, which can be calculated in encrypted type by all ballots recorded in authentication server encrypted with FHE. Without compromising system architecture, the scheme could grow rapidly to more cloud servers. Using cloud facilities for a defined election duration restrains each

election cycle purchasing fresh equipment. Therefore, this is cost effective.

F. Blockchain

A blockchain is an increasing array of documents; each block called frames includes the prior blocks' cryptographic hash, timestamp, and transaction data. The suggested system in [29] and homomorphic obligations depended on the mini-blockchain system. The goal is to make the mini-blockchain more private.

Over the past few years, there has been an outbreak of cryptocurrencies and associated study articles attempting to address issues with the mini-blockchain system that altered the initial blockchain in order to decrease its size and promote enhanced block size.

1) Homomorphic Mini-blockchain Scheme: The mini-blockchain (MBC) was intended to use the "account tree" to enhance the initial blockchain to record each account's equilibrium. Therefore, there is no need to store accounts in the blockchain indefinitely, only the latest purchases and the current account tree. Therefore, the mini-blockchain is much more scalable than the initial blockchain since the mini-blockchain only expands when creating fresh accounts. The mini-blockchain consists of three components:

1) Account tree: the account tree is a Merkle tree (a tree where each leaf node is labeled with an information block number), all the records in a block; each account is an information block with an email and balance.
2) Transaction tree: a Merkle tree for all operations in a particular group, each transaction being a shift to a amount of records.
3) Proof chain: is merely a sequence of frames where each block includes a nonce, the account tree's top hash and the prior block's hash.

- The mini-blockchain works very much like the standard blockchain very much. Each miner separately checks the transaction accuracy and produces a transaction tree with the right operations. Each miner also modifies the account tree to represent the transaction modifications.
- The miner may submit nonce for inclusion in the mini-blockchain to the network. The nodes need only maintain a finite amount of account forests and transaction trees so that the account tree and an elderly block's transaction tree will be removed after a fresh block is formed. Only the whole evidence chain has to be recorded. This scheme only tries to change how accounts and transactions are coded into the mini-blockchain, the homomorphic mini-blockchain (HMBC) scheme provided some improvements to minimum output values, multi-signature addresses, and blind signatures on the scheme. The method used by the HMBC system (Address reuse) is a straightforward study to find reused addresses. Therefore, privacy is essential, the HMBC system enforces the use of single-use addresses while making it possible for customers to have a set address. Each transaction has its own provisional address that is not advertised as belonging to a particular individual. Therefore, nobody can connect them to their owner's identity.
- The transaction numbers will be encrypted in all HMBC. Therefore, they cannot be used to link accounts with identity or filter the blockchain transactions. Because of the use of set addresses, screening buttons, indigenous multi-signature help and blind signing. The mini-blockchain system is more personal and scalable than Bitcoin.

G. Data Mining with Privacy Preserving

Data mining is a computing instrument commonly used today that seeks to obtain helpful data from multiple databases. Nowadays, with the big quantity of data being generated, stored in a remote database (using cloud computing), data privacy and confidentiality concerns arise due to the lack of secure storage and mining security algorithms. It allows arbitrary computation of encrypted information, which is a solution aimed at preserving safety, confidentiality and information privacy. This offers techniques for ensuring the confidentiality and privacy of fully homomorphic encryption based database mining.

Homomorphic encryption is an area of modern cryptography that enables arbitrary computation to be completed on a ciphertext, the encrypted result matching the sequence of operations performed in the original text is still achieved.

Homomorphic encryption is an area of modern cryptography that enables arbitrary computation to be completed on a ciphertext; and the encrypted result that matches the operation sequence performed in the original text is still achieved.

There are two kinds of homomorphic encryption, some of which are homomorphic, and complete homomorphic encryption. The partially homomorphic encryption is described when the quantity of encrypted information operations is limited. Fully homomorphic encryption, however, is a cryptographic system that enables you to perform an arbitrary set of mathematical operations in the resulting cipher text.

Fully homomorphic encryption can be evaluated homomorphically with any circuit, enabling the creation of programs that can run their input encoding to produce their output encryption. Programs like homomorphic never decode their inputs, untrusted third parties can use them and their input data and internal processes are therefore hard to reveal. The existence of a fully homomorphic and effective cryptographic system would have major practical effects on outsourcing of personal computing.

1) Privacy in Data Mining: Data mining helps to extract helpful understanding from big information sets, However, the processes of collecting and disseminating information may pose an inherent risk of confidentiality and privacy. Some private data about individuals, businesses and organizations must be removed unless such data is encoded before it is communicated or released. It has thus become a very significant problem to preserve privacy in information mining.

The term originated as Privacy Preserving Data Mining (PPDM) which relates to the data mining area to prevent unsolicited disclosure of sensitive information. Methods of mining over traditional information statistically analyze and model the information, while security against disclosure of personal data records is mainly worried with privacy conservation.

The term Data Mining Data Preservation-PPDM has been implemented. Two basic issues in PPDM: 1) the privacy of information compilation and 2) the privacy of several personal businesses during the mining phase of a partitioned information set [30].

The goal of maintaining information mining privacy (PPDM) is that relevant knowledge must be extracted from large amounts of information while protecting sensitive information. Thus, during data mining, the method of maintaining data privacy and confidentiality needs fresh techniques and advances, particularly in the field of modern cryptography.

The surveys have identified address schemes that use fully homomorphic encryption that can be implemented straight in data mining. Fully homomorphic encryption – based on a feasible, efficient solution that ensures the privacy, confidentiality and integrity of mined data. The FHE is a solution for statistical analysis of encoded data while preserving privacy and confidentiality.

VI. Discussion and Future Work

Homomorphic encryption is a promising technology to enable massive valuable operations on encrypted data. We predict more work on how Homomorphic techniques could lead scientist to perform meaningful operations on Blockchain transactions in order to analyze the flow of financial processes. Moreover, we believe homomorphic operations contribute significantly to the field of secure healthcare records. Finally more work is needed to apply the concept of homomorphic encryption for cloud environment. Our future work will be about illustrating a full systematic review of Homomorphic encryption as well as investigating its opportunities and challenges.

VII. Conclusion

In this paper, we give a review on HE developments and its privacy preserving applications. We first showed that it is essential to address the privacy issues in some promising technologies such as cloud computing before they can be widely adopted. HE schemes were considered highly valuable in ensuring data privacy since they allow meaningful computations to be performed in an encrypted form without decrypting the data, especially for outsourcing data to a distrusted party. We reviewed the HE privacy preserving applications in the field of Vehicle communication, Signal processing, Healthcare, Blockchain, Data-mining, Electronic voting and cloud computing.

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Convolutional Neural Network and Topic Modeling based Hybrid Recommender System

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***Abstract*—In today's personalized business environment, organizations are providing bulk of information regarding their products and services. Recommender system has various accomplishment on exploiting auxiliary information in matrix factorization. To handle data sparsity problem most recommender systems utilized deep learning techniques for in-depth analysis of item content to generate more accurate recommendations. However, these systems still have a research gap on how to handle user reviews effectively. Reviews that were written by users contain a large amount of information that can be utilized for more accurate predictions. This paper proposes a Hybrid Model to address the sparsity problem, convolutional neural network and topic modeling for recommender system, which extract the contextual features of both items and users by utilizing Deep Learning Convolutional Neural Network (CNN) along with Topic Modeling (Lda2vec) technique to generate latent factors of user and item. Topic Modeling is used to capture important topics from side information and deep learning is used to provide contextual information. To demonstrate the effectiveness of the research, an extensive experimental sets were performed on four public datasets (Amazon Instant Video, Kindle store, Health and Personal Care, Automotive). Results demonstrate that the proposed model outperformed the other state of the art approaches.**

Keywords*—Recommender system; collaborative filtering; Lda2vec; Convolutional Neural Network (CNN); data sparsity problem; user reviews

I. Introduction

Recommender systems have become the core component of many e-commence organizations (i.e. movies web sites, e-libraries, articles, news, music, etc.) which avails it to predict the liking and disliking of users. To increase their business revenues companies are widely using these intelligent systems. Recommender systems gained much importance with extensive usage of the internet. It focuses on user needs and providing what they possibly want. Recommender systems are information retrieval system which help users to get their required data from this bulk of information [1].Both users and organizations can get benefit form recommender systems. It helps user to save plenty of time while searching for online product and helps in improving the decision-making process of the organization [2].

Various recommendation techniques have been proposed in literature and are classified as collaborative filtering technique (CF), content-based filtering technique (CBF) and hybrid filtering technique (HF) [1]–[4].Amazon, Google News, Netflix and many other organizations are using Recommender System to target their customers. CF is one of the most widely used techniques in recommender system it can make recommendations on the basis of historical information or previously buying behavior of users to predict which item is liked by the user.This technique is based on user-item rating matrix which utilizes given users rating and predicts unknown ratings in the sparse matrix [5].

CF is further categorized into memory-based collaborative filtering and model-based collaborative filtering. Memory-based collaborative filtering applies the entire database i.e. likes, votes, clicks, etc. for rating prediction. In model-based filtering, deep learning techniques are used to construct models,train machine to learn those models and use those models to predict ratings of unrated items [5]–[7].

Cognitive filtering is another name of content-based filtering. CBF recommend item even if no rating to that item is available in the database. It is based on the content provided by user in the form of rating or reviews. The more information provided by the user more accurate recommendations will be provided [8].It focuses on machine learning algorithms that capture user and item choices into user and item profiles respectively and recommend items to users having higher similarity with the user profile. To understand what user and item profile are considered movies as items that have different actor, director, genre etc. and user profile has demographic information, user clicks, ratings and selected items i.e. movie [9], [10].

Hybrid filtering is the union of both collaborative and content-based filtering. Both CF and CB filtering have their own pros and cons, the suitability of each approach depends on the situation in which it is used. In order to get benefit from both of them, hybrid filtering is used which suppresses the limitation of one technique alone. The hybrid filtering technique provides more accurate recommendations than the other two techniques and the performance of recommender systems using a hybrid filtering technique is much more than RS which separately using content or collaborative filtering technique. Different hybrid filtering techniques have been proposed in the literature, however, recommender system still requires some improvements on issues like data sparsity and cold-start problem [2].

Data sparsity problem is one of the most challenging assignments in recommender system. Data sparsity problem occurs when the user rated only a few items or there exist deficient feedback data. Many real-time applications are facing this sparsity issue. CF fail to provide recommendation to user with scarce rating data. Most CF use rating matrix for recommendation task and ignores the important information available in user reviews which improves rating prediction. Various techniques have been proposed in the literature to handle data sparsity problems by combining user ratings and reviews. However, there exists a research gap of data sparsity in recommender system which need improvements and more accurate recommendations [11], [12].

To deal with this data sparsity problem in RS, a hybrid model is proposed which fuses rating data along with the information (reviews) of both user and item. The proposed model is termed as the Hybrid model of Convolutional Neural Network and Topic Modeling (HCNNTM) for recommender system which handles data sparsity problem, model unites CNN + Lda2vec into PMF to achieve latent factors of both the user and item enriched with topic information. PMF is used because it outperforms on sparse, imbalance and large datasets, which provides more efficient and accurate recommendations. Experimental evidence illustrates that using deep learning and topic modeling techniques along with the side information of both user and item content improves the performance of recommender system. The major contribution of this study suggested a Hybrid content Embedding Model for Recommender System, HCNNTM, which combines topic modeling with deep learning techniques to provide topic enriched contextual features of both user and item which will improve accuracy of rating prediction. This research uses two convolutional neural networks for item side information and Lda2vec for user side information and generates latent factors of both user and item. Experimental findings show that the proposed model not only handle data sparsity problem but also enhance rating prediction accuracy when compared with other state-of-art models.

The organization of this paper follows the related work of the RS in Section 2; the proposed model is described in Section 3; experimental findings and Results comparisons and discussion are presented in Section 4. Finally, Section 5 will present the conclusion and future work.

II. Related Work

An immense amount of work on the recommender system using side information has been studied. This section will highlight the researchers' contribution and its relevance to the proposed technique.

Earlier, a recommender system uses either collaborative filtering or content-based filtering for recommendation task. Where, in collaborative filtering method, items are recommended on the basis of users behavior. Some examples of CF are nearest neighboring modeling [13], matrix factorization, singular value decomposition, non-negative matrix factorization is used to handle data sparsity problem by using item collaborative filtering, user collaborative filtering or both [14].

Probabilistic matrix factorization has been proposed in [15], where the performance is much better than SVD. A variety of techniques have been developed to upgrade the performance of PMF by considering the auxiliary information and introduce Bayesian and Generalized version of PMF [16]–[19].

Trust-aware collaborative filtering is proposed in [8] which utilizes CF to provide recommendation on the basis of trusted users with other trusted users, indoor to handle malicious users in the system which effect the accuracy of recommendation. Eigen taste algorithm is proposed which utilizes global queries to extract user ratings and apply principal component analysis PCA for making recommendations. Content-based filtering is another technique used for recommendation task, it recommends items on the basis of content (side information) of items.

In [20], authors proposed a method known as Meta-product2vec, which utilizes the side information by adding it to previously developed product2vec approach which utilizes synergy of local product information for generating distributed representation and neglect metadata information of item available only on training time in Meta-product2vec method which improves a recommendation performance. Content-based filtering PRES technique is proposed in [21] to recommend small home improvement articles. It basically makes recommendations by comparing user profiles with available document contents. However, they cannot handle data sparsity efficiently. Hybrid approaches have been developed by researchers with unite good features of both collaborative and content-based recommendation to overcome the limitations of CF and CBF [2].

Restricted Boltzmann Machine is used by [22] to find similarity between items and then map them into collaborative filtering. Considering the cross-domain matrix factorization coordinate system transfer method has been introduced in [23]. A cross-domain recommendation has been studied in [24], where no mutual user or item exists among cross domains. The proposed generative model for finding similar group between different domains. A multi-view deep neural network (MVDNN) model has been proposed to solve cold starch problem in [25], which maps user and item view in shared space. User features are obtained from browsing the history of users and recommend movies on the basis of maximum similarity with user.

HFT model is proposed in [12] which uses a topic modeling technique. The proposed model is the combination of latent dimension and latent review topics for interpreting rating dimension of either item or user reviews and results showed that technique outperforms as compared to other models that only used rating or review. Collaborative deionized auto encoder (CDAE) is proposed in [26] to handle/predict top-N recommendation by using user rating matrix, not considering side information such as reviews. A unified model proposed in [11] combines collaborative filtering and content-based filtering to solve cold starch problem. It uses a topic modeling techniques from user reviews to improve recommendation results.

LDA was proposed in [34], which is basically a topic modeling technique to capture latent topics and to address the limitation of word vector which are represented locally using w2v [36]. TWE was proposed in [35] to predict the context of words using topic and allow those words to have different word vector representations having different topics. Lda2vec is proposed by Moody in [33], which solves the limitation of previously mentioned techniques by considering both local and global meaning of documents. It integrates LDA and Word2vec to build context vector during training by utilizing both document vector and topic vector.

Recently, a deep learning technique has gained much importance in artificial intelligence, speech recognition and machine learning domain. These techniques are widely used for developing a recommender system using both collaborative and content-based filtering. A deep learning technique is used in [27] termed as Marginalized De-noising Auto-encoder (MDA), which integrates PMF and Margined Deionized auto-encoder to learn latent representation of items by neglecting randomly corrupted feature and reduces computational cost of training.

In [28], researchers used a deep learning approach called Hybrid-CF and content-based music recommendation which learn latent factors from music content using matrix factorization and apply deep learning techniques to regenerate them for better songs recommending. Deep Conn model is proposed in [29] which uses both user and item embedding as latent model of user and item and model interactions between them by applying factorization machines. It uses two neural networks and maps them into shared layer for making recommendations. The proposed model generates a vector representation of user and item content by utilizes side information along with rating data. It combines deep neural networks (CNN) along with topic modeling (Lda2vec) for the generation of user and item latent factors to improve recommender system accuracy.

III. Proposed Methodology

The proposed model is discussed in this section, which mainly consists of two steps. At first, the probabilistic matrix factorization is used to combine both topic modeling and deep learning technique. PMF unites Lda2vec and CNN for utilizing both rating and review information (user side review and item side review). Furthermore, CNN model was introduced which was used for generating item latent factor and LDa2vec model used for generating user latent factors. The overview of the proposed system is demonstrated in Fig. 1.

A. Probabilistic Matrix Factorization

As model integrates CNN and Lda2vec into PMF, based on which the PMF model explanation is considered first. Probabilistic matrix factorization (PMF) is a matrix factorization technique used to represent both user and items in shared d dimensional latent space where user and item latent vector can be represented as $u_p \in A_{ui}^d$ $i_q \in A_{ui}^d$.In order to predict whether user will like an item or not, dot product of both user and item latent features will be represented as $P_{ui} = (U_p^T.I_q)$.Thus conditional distribution of predicted ratings is given as:

$$P(A_{ui}|U, I, \sigma^2) = \Pi_u^p \Pi_i^q N(P_{ui}|u_p^t.i_q, \sigma^2) \tag{1}$$

Where $N(x|\mu, \sigma^2)$ is Gaussian normal distribution,probability density function with mean and variance.The proposed model can minimize the regularized square error loss by using both user and item latent factors $U = (u_u)_{u=1}^p$ and $I = (i_i)_{i=1}^q$ as shown in equation.

$$\min_{u,i} \Sigma_{p,q}(A_{ui} - U_p^t.I_q)^2 + \lambda_u||U_p||^2 + \lambda_v||I_q||^2 \tag{2}$$

Where λ_u and λ_v are the parameters used for regularization,actual rating prediction $A_{ui} >$ ZERO if user rated an item and it will be zero if user dose'nt rate item.To predict weather user rated an item or not equation is given below:

$$P_{ui} = (U_p^T.I_q) \tag{3}$$

For user latent vector, the contextual topics from Lda2vec, user-contents (Y), and epsilon variable as zero-mean spherical Gaussian noise to optimize latent factor of user are considered.

$$U_p = Lda2vec(Y) + \epsilon_p \tag{4}$$

$$\epsilon_p \approx N(0, \lambda_u I_d) \tag{5}$$

Consequently, a conditional distribution for user latent factor is represented as:

$$P(U|Y, \lambda_u) = \Pi_u^p N(U_p|Lda2vec(Y), \lambda_u I_d) \tag{6}$$

Similar to user latent factor, for an item latent factor the weights of CNN (W) along with item-contents (X), epsilon variable and Gaussian noise is used and can be represented as:

$$I_q = CNN(W, X) + \epsilon_p \tag{7}$$

$$\epsilon_p \approx N(0, \lambda_v I_d) \tag{8}$$

Conditional distribution for item latent factor is represented as:

$$P(I|W, X, \lambda_v) = \Pi_i^q N(I_q|CNN(W, Y), \lambda_v I_d) \tag{9}$$

For both user-item latent factors, weight of CNN (W) along with user-item-contents document (Y, X) and Gaussian noise is used.

$$P_{ui} \approx N(U_p^T.I_q, c_{pq}) \tag{10}$$

In (10) c_{pq} is a confidence parameter whose larger value represents more accurate rating. If $A_{ui} > 0$ i.e. user p rated an item q, and if $A_{ui} = 0$ i.e. user does not rated any item. The aforementioned details explained how PMF can deal with unknown ratings in the sparse rating matrix.

B. Convolutional Neural Network Model for Content Generation

The objective is to exploit contextual information for regularizing user and item latent factors in matrix factorization for this convolutional neural network (CNN) is utilized to generate content embedding of both users and items. Embedding Layer of CNN can convert unprocessed documents into meaningful numeral matrix based on the dimension/size of words. It is initialized with fast text [31] to generate content embedding of items and convert it into dense matrix which is used as an input document. Item are represented as a sequence of word vectors. Item-content with n words having s dimension can be represented in ID (input document) as:

$$ID = we_1 \oplus we_2 \oplus we_3 \oplus \cdots we_n \tag{11}$$

where we is word embedding,$\oplus$ shows concatenation operation to maintain order or words in input documents these techniques

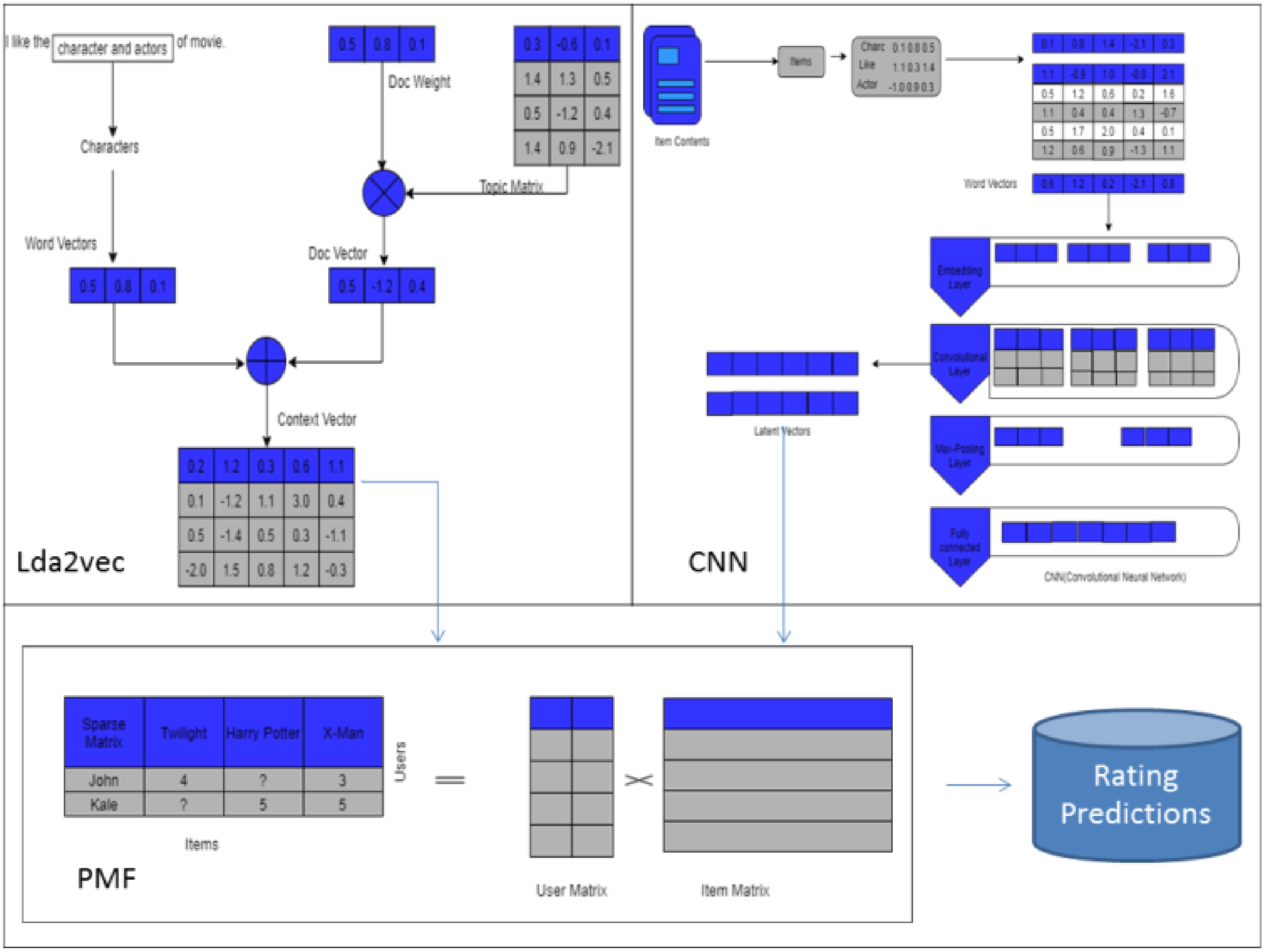


Fig. 1. Proposed Model Diagram

will solve the problems in traditional bags-of-words model.In convolutional Layer contextual information of words present in review document was captured. Various window sizes are used to get content from documents because convolutional kernel determines the number of surrounding words.It consists of m neurons to apply convolutional operation on word vectors of each document ID to get new features. Each neuron m in convolution kernel $L_m \in \Re^{s \times t}$ is passed through different window size t and s dimensional word vectors represented in the equation as:

$$H_m = f(ID \otimes L_m + b_m) \tag{12}$$

where $H_m$represents the feature map in convolutional layer,$\otimes$represents convolutional operation, b_m represents bias which could be any real number, and f represents the activation function which could be sigmoid, ReLU and tanh. In this work, ReLU is taken as activation function to dodge vanishing gradient problem then (12) will become:

$$H_m = ReLU(ID \otimes L_m + b_m) \tag{13}$$

A $Max - PoolingOperation$ is performed on specific kernel Hm to obtain maximum features from convolutional layer. Each feature mapped which has the highest value can be captured and considered as most important features for rating prediction. It ignores extra contextual features in the convolutional layer and handles the dynamic length of document by providing new fixed-length feature vectors which will improve the performance of system as shown in (14). Only one feature is extracted from one kernel so different filters of various window sizes have been used to get multiple features and the output vector is represented as (16).

$$O_m = \max[H_1, H_2, H_3, \cdots, H_{n-t+1}] \tag{14}$$

$$O = [o_1, o_2, o_3 \cdots, o_r] \tag{15}$$

where r represent the number of convolutional kernels.

In $OutputLayer$, top features from the max-pooling layer ought to be converted in require assignment. These high-level feature O are passed to $d-$ dimensional vector space of user and item by using non-linear projection:

$$E = \tanh(M_2 \times \tanh(M_1 \times +b_1) + b_2) \tag{16}$$

Where M_1 and M_2 are the projection matrix, b_1 and b_2 are bias functions. The aforementioned process can change crude documents as an input document and return latent vectors of d-dimension as output.

$$I_q = CNN(W, X) \quad (17)$$

C. LDA2VEC for Topic Extracting

Lda2vec is the combination of word2vec model (Natural Language Modeling tool) with most commonly used topic modeling technique LDA (Latent Dirichlet Allocation) to utilize best features from both [33]. Lda2vec model combines "globality" and "locality" idea of word prediction from word2vec and LDA. Lda2vec summed up word embedding with LDA vectors and compare them with latent word topics. Finally, the conditional probability model is applied to predict final topics. Thus model predicts words from not only the given context but also from the probability of coexistence of other words. For local word prediction, (18) is utilized.

$$P = (P_{tar}|P_{piv}) \quad (18)$$

Where P_{tar} is target word and P_{piv} is pivot word probability respectively.While for global word prediction (19) is used.

$$P = (P_{tar}|P_{topic}) \quad (19)$$

Where P_{topic} is topic probability,for which Lda2vec is used that predict both locally and globally as:

$$P = (P_{tar}|P_{piv} + P_{topic} + P_{document}) \quad (20)$$

Where $P_{document}$is a sparse LDA vector, P_{topic} is contextual topics, P_{piv} is pivot word.Procedure describes above uses Lda2vec model as a function that takes inputs from user-content and returns user latent vector. An obtained latent vector is supplemented with semantics content enriched with topic contents. So the resultant user latent vector can be represented as:

$$U_p = Lda2vec(Topic, Y) \quad (21)$$

D. Hybrid Model of CNN and Topic Modeling

In a proposed model, a description document of both users and items (which have reviews written by user to specific items) is utilized. User contents provide information regarding users interests whether they like or dislike a particular product while item contents provided information about item properties. The proposed model is termed as Hybrid model of convolutional neural network [30] and topic modeling for recommender system as it combines both mentioned techniques into probabilistic matrix factorization to acquire latent factors of both user and item so that a better recommendation can be provided. It concurrently learns the dense word vectors using Dirichlet distributed topic mixture [33]. Union of CNN (deep learning technique) + Lda2vec (topic modeling technique) allows system to get more global features and provides better understanding of the review document. CNN is used to capture contextual information and Lda2vec is used to capture topic information available in review text. These extracted features along with topic details provide good understanding of memory and model-based collaborative filtering. To provide more efficient and accurate recommendations model further utilizes PMF which outperforms on sparse, imbalance and large datasets. Experimental results show the effectiveness of the above proposed model [15].

Lda2vec captures topics both locally and globally, which are further combined with deep learning techniques to improve rating predictions. After getting latent factors of both users and item model initialize PMF which analyze reviews and rating to provide better recommendation to users.

IV. Performance Evaluation

Algorithm proposed in this research is evaluated and compared with already proposed state of the art model. Model exercised a five-fold cross-validation test to check the accuracy of rating prediction.

A. Dataset Preprocessing

In this paper, Amazon dataset[1] is used which has 22 further sub-categories of products. It consists of reviews and product meta-data. In this experiment, four different datasets of Amazon instant video, auto motives, health and personal care and Kindle store (AIV, Auto, HPC, KS) are used to evaluate the performance of proposed model. It has 142.8 million reviews covering May 1996 - July 2014. K-core dataset is used in these experiments, which means each user and item has K reviews. Table I below show the statistic of dataset.

TABLE I. The statistics of Amazon Datasets

Datasets	No.of Users	No.of Items	No.of Ratings	No.of Reviews	Scale
AIV	5130	1685	37126	37126	[1 - 5]
KS	68223	61934	982618	982618	[1 - 5]
Auto	2928	1835	20473	20473	[1 - 5]
HPC	38609	18534	346355	346355	[1 - 5]

For evaluating performance of the proposed model, the dataset splits into three categories (i.e. training, validation, and testing sets) using ratio of 80%, 10%, and 10%. As it requires reviews of both users and items rating predictions. Real dataset contains reviews of both (user and item) in single item. First user-content and item-content are separated, then every user and item is represented in a sequence of reviews. Furthermore, the data is pre-processed by removing stop words, td-idf vectorization is used to remove words from document whose frequency is 0.5, fixing the vocabulary size to 8000, setting maximum length of document 1200, and introduce two thresholds tc = 0.5 and tr = 0.8 to control the number of sequence for each user/item and to control the length of the sentences in each user/item. Items having min-rating is 1 removed along with all other items who have no ratings to get more accurate and precise recommendations. This pre-processed information is then passed to fast text [31] word embedding technique to produce vector representation of users and items. For CNN fast text model is initialized with built-in sentences with min-count = 1, dimension size d = 200. Various window size [3-5] is used in convolutional layer of CNN model with dropout ratio to avoid over fitting problem. The number of epochs is fixed to 1 and batch size of 128, 256, and 512. Embedding layer is initialized with these word vectors to get contextual features items. For Lda2vec window size = 1 is used to collect every word surrounds the pivot words. To clean and tokenized user-content the script is removed, preprocess and corpus functions of Lda2vec is applied as pre-trained model.

[1]http://jmcauley.ucsd.edu/data/amazon/

After getting contextual information in the form of user and item latent vectors PMF is initialized with these latent vectors which play a vital role in improving prediction accuracy.

B. Evaluation Matrices

Different types of evaluation techniques have been used in literature to check the performance of recommender system [32]. Evaluation matrices are divided into three categories:

1) Prediction matrices (MAE, RMSE)
2) Classification matrices (RECALL, PRECISION)
3) Rank Measure (Measuring ordering of items performed by recommender system).

In experiments RMSE is used for rating predictions and can be calculated as:

$$RMSE = \sqrt{\frac{1}{N}\Sigma_{u,i}\Big(A_{ui} - P_{ui}\Big)^2} \tag{22}$$

Where; A_{ui} is actual ratings,P_{ui} is predicted ratings,N represent total number of ratings,u represent user,i represent item. Miminum value of RMSE represent better rating prediction.

Along with RMSE, Precision and Recall metrics are also used as evaluation matrices to measure the quality of recommendation. Two classes namely relevant (have rating >=3) and irrelevant (have rating <3) are defined to recommend items to users.

$$Precision = \frac{truepositive}{truepositive + falsepositive} \tag{23}$$

$$Recall = \frac{truepositive}{truepositive + falsenegative} \tag{24}$$

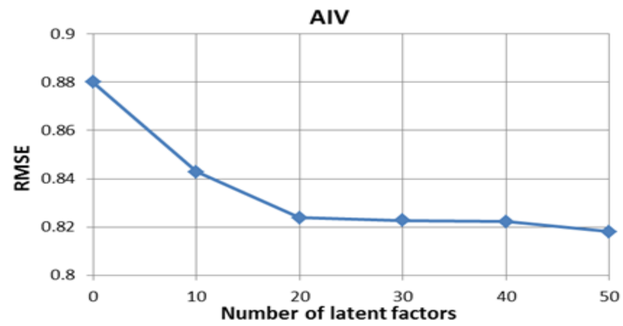
Where; $truepositive$ means recommend relevant item to user,$falsepositive$ means recommend irrelevant item to user ,$falsenegative$ means relevant items are not recommended to user.

C. Results and Discussions

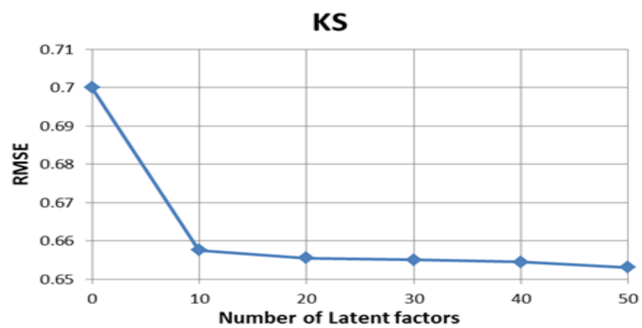
Experimental environment of this research is Ubuntu platform, with core i7-7700 CPU, 2 GPU, 16 GB RAM, 2 TB Disk. All implementation is done in python for CNN implementation which uses Keras framework with tensor flow at back end. Extensive set of experiments is performed on the Amazon dataset to study the impact of two different parameters latent factors and convolutional kernels. In Fig. 2 and Fig. 3 latent factors varies from 10 to 50 and convolutional kernels vary from 50 to 200 to check sensitivity of the proposed model against those parameters. Fig. 2 and Fig. 3 shows a decreased RMSE which improves rating prediction accuracy.

For top-N recommendation, the precision and recall matrices have been computed, which divides data into two classes as relevant and irrelevant classes. Rating above three or equals to three are considered as relevant items and all remaining items who have ratings less than this threshold value are considered as irrelevant items. Fig. 4 shows the performance of proposed model in terms of top-N recommendation.

The performance of proposed model is evaluated by using different parameter settings and results are shown in Table II which displays RMSE of all datasets and overall performance of the proposed model with other models PMF [15], ConvMF



(a) Amazon Instant Video



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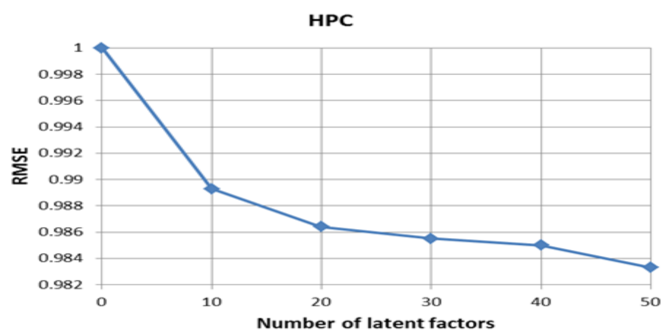
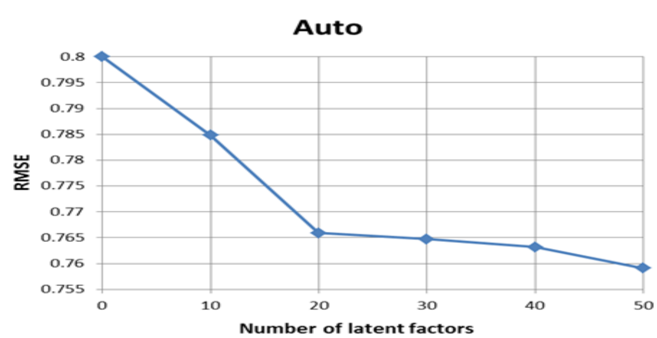
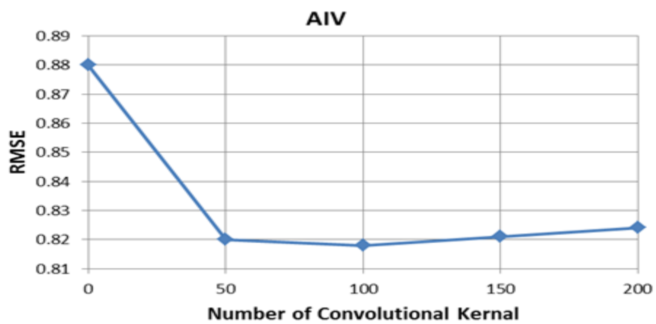


(c) Health and Personal Care

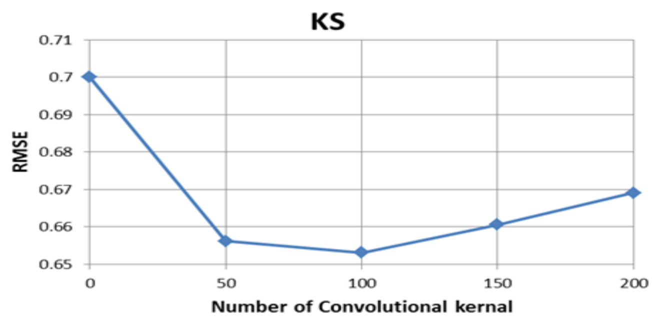


(d) Automotives

Fig. 2. Performance of Proposed Model on Datasets with different Latent Factors (D)



(a) Amazon Instant Video



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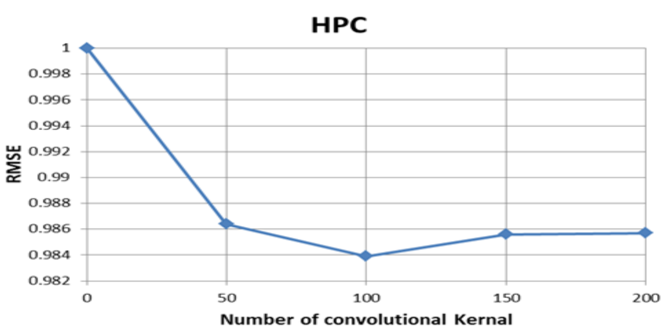

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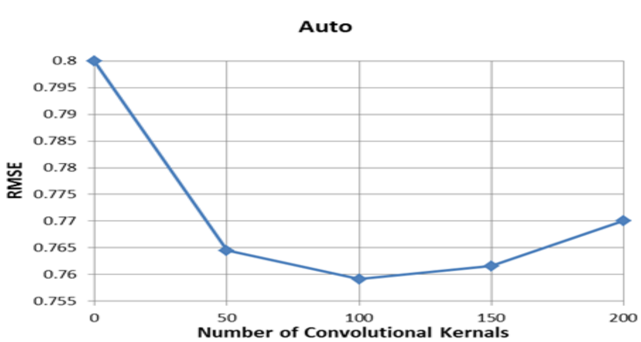
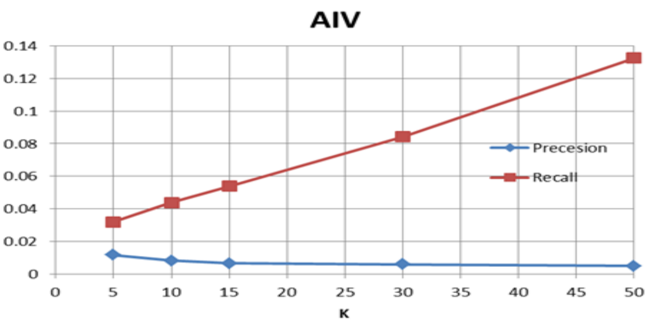
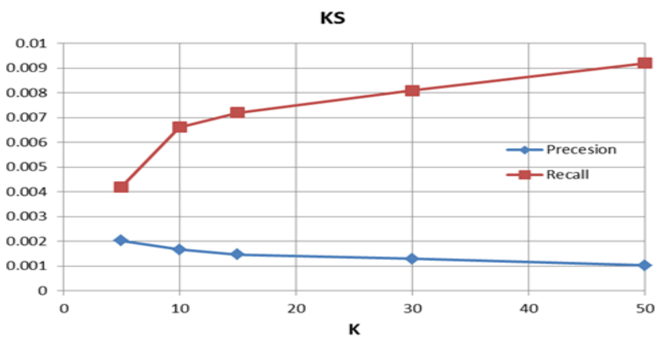


(d) Automotives

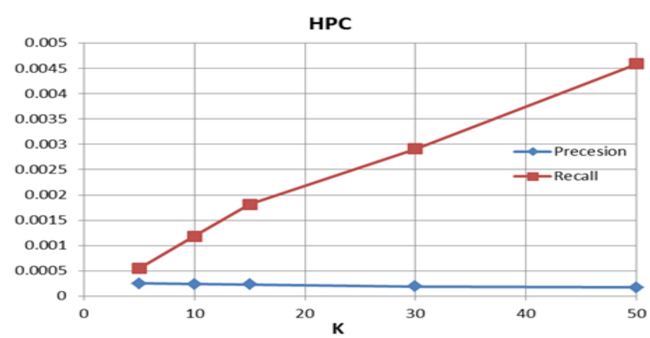
Fig. 3. Performance of Proposed Model on Datasets with different Convolutional Kernels.



(a) Amazon Instant Video



(b) Kindle Store



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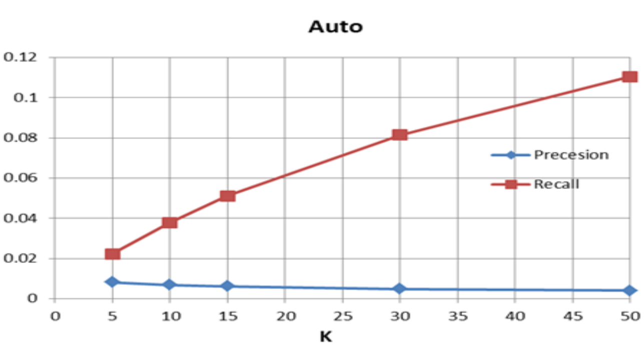

(d) Automotives

Fig. 4. Precision and Recall

[30] and DeepConn [29]. RMSE of PMF in aiv dataset ≈ 1.2098, ConvMF ≈ 1.0159(aiv) and in DeepConn ≈1.0122. This shows that ConvMF gains better performance then PMF it means that by considering side information recommendation accuracy has been improved. PMF uses only rating data. ConvMF used both ratings data along with side information of items but they neglect side information of user side which plays a vital role in rating prediction.Moreover,DeepConn utilizes side information of both user and item contents which bring better results and improve recommendation accuracy.

In Table II result shows that DeepConn-Item, DeepConn-User and DeepConn-Both outperform ConvMF in terms of RMSE.Results depict that taking advantage of both user and item content embedding give more efficient and stronger recommender systems. This might be substantiated by comparing HCCTM-Both with HCCTM-User, HCCTM-Items and in contrast with DeepConn-Items, DeepConn-Users and DeepConn-Both, ConvMF and PMF. HCCTM-Both improves HCCTM-User and HCCTM-Item on AIV dataset by 2.45% and 16% respectively. Similarly, HCCTM-Both outperform DeepConn-Both, ConvMF and PMF by 19.42%,28.79%,39.18% on AIV dataset respectively. Similar trend can be seen in remaining datasets.

Proposed paradigm considers information of both user and items content to improve the accuracy of ratings predicting. Finally, evidence shows that proposed model outperform ConvMF, PMF and DeepConn. RMSE has improved significantly which depicts that by using the topic information along with neural networks, provide a more accurate and effective recommender system.

TABLE II. PERFORMANCE ANALYSIS OF OUR PROPOSED MODEL WITH OTHER MODELS

$Dataset \rightarrow$ $Models \downarrow$	AIV $RMSE$	KS $RMSE$	HPC $RMSE$	$Automotive$ $RMSE$
PMF	1.2098	0.9657	1.3348	1.1124
$ConvMF$	1.0159	0.9374	1.2308	0.9178
$DeepCoNN-Items$	1.0142	0.9184	1.2183	0.9134
$DeepCoNN-Users$	1.0144	0.9187	1.2185	0.9137
$DeepCoNN-Both$	1.0122	0.9046	1.2036	0.9113
$HCCTM-Items$	**0.9779**	**0.8015**	**1.0892**	**0.9026**
$HCCTM-User$	**0.8425**	**0.7546**	**1.0318**	**0.8234**
$HCCTM-Both$	**0.8180**	**0.6531**	**0.9833**	**0.7591**

V. CONCLUSION AND FUTURE WORK

In this paper, a hybrid model of convolutional neural network and topic modeling for a recommender system that incorporates CNN + Lda2vec into probabilistic matrix factorization to seizure the content information of both items and users is presented. The user and item contents are exploited for rating predictions. The model learned a latent factor of user and item from both ratings and reviews of user. A collaborative filtering technique PMF is used for rating prediction. The suggested model is applicable to other datasets having both user and item contents. The experimental finding shows that the proposed model performs much better when compared with other state of the art model (i.e. PMF and ConvMF). The aforementioned technique can effectively learn latent factors for both user and item, thus provides high accuracy and better performance.But briefly reiterated the facts that there may be room for more improvement so for further research,examination and incorporation of time factor to generate user and item latent will be evaluated. Also, it would be interesting to eliminate noise problems in the recommender system as it will affect the performance of the recommender system.

VI. ACKNOWLEDGMENT

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Data Rate Limit in Low and High SNR Regime for Nakagami-q Fading Wireless Channel

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***Abstract*—Adequate data rate is always desired in wireless communication channels. Previously, few fading models were used to model wireless communication channels and to perform analysis on them. In this paper, analyses of data rate limit of single-input single-output (SISO) wireless communication system over Nakagami-q fading channels are presented. The calculation of capacity has been carried out using small and large limit argument approximations. The analytical solution for channel capacity is presented using small and large limit argument approximations. Where small and large limit argument approximations correspond low and high signal-to-noise ratio (SNR) regime. Behavior of channel capacity with respect to SNR and fading parameter respectively has been investigated deeply. The comparison of the channel capacity behavior for both low SNR and high SNR regime and have also been done and analyzed. It has found that the channel capacity increased with increasing SNR in low SNR regime. The channel capacity also behave in the same manner in high SNR regime as well.**

Keywords*—Wireless communication; Nakagami-q fading; SISO channel capacity; low SNR regime; high SNR regime

I. Introduction

Having a good data transfer rate in wireless communication system is always expected for users. Downloading and uploading information faster is becoming more and more demandable with the advancement of technology. In order to do so, the capacity of the wireless communication system needs to be increased. Shannon [1], first introduced the concept of information theoretic capacity. Essential outlines of communication over wireless channel was characterized in [1] by Shannon. Since then many wide research has been done on information capacity for different distributions. Systems evolved from single-input single-output (SISO) to multiple-input multiple-output (MIMO) over the time period. In [2], authors discussed about SISO and MIMO channel capacities. They compared SISO capacities among different distributions which includes Uniform distribution, Gaussian distribution, Chi-square distribution [2]. Authors evaluated the performance of SISO, SIMO and MIMO antenna systems in [3]. In [4], authors presented results based on their findings on the capacity of discrete-time Rayleigh-fading SISO and MIMO channels.

Nakagami-m, Rician and Rayleigh distributions are popular distribution models for research on SISO, SIMO, MIMO channels. Besides these distribution there is Nakagami-q distribution also known as Hoyt distribution which is a type of fading distribution that under indisputable conditions serves a decent model. In [5], authors state that this distribution permits the modeling of the environment of propagation without a presiding component over the scattered waves which is also known as a situation of Non-line of Sight. Over generalized fading channel, it has been found that, Nakagami-q distribution has application in the error execution assessment of digital correspondence system [6]. Likewise, this fading channel is usually observed in satellite link subject to powerful ionospheric glimmer and intensely shadowed condition [7]. In inter-satellite communications, instantaneous signal to noise ratio follows the log-square-Hoyt distribution [8]. For performance analysis and other studies which are related to mobile radio communications, the Nakagami-q model is being used more frequently.

In this research work, study of the data rate limit of SISO wireless communication system over this Nakagami-q fading channels is done. For this, the calculation of the capacity for low and high SNR regimes based on Nakagami-q distributions including the comparison of them have been done in order to analyze how consistent and good the data rate limits are with respect to instantaneous SNR and fading parameter.

The rest of the paper contains the followings. Nakagami-q distribution in Section 2. System model for this study in Section 3. In Section 4, the capacity calculations for low and high SNR regimes for Nakagami-q fading wireless channels. Section 5 contains the results and analysis. At last, the concluding remarks of this work are presented in Section 6.

II. Nakagami-q Distribution

Nakagami-q distribution or Hoyt distribution is usually used to depict the transient signal variation of certain wireless communications systems subject to fading [9]. This distribution can be defined as the distribution of modulus of complex Gaussian random variables with zero mean and unequal variances [10]. The probably distribution function simplified as PDF, of this Nakagami-q distribution is given in [11] by,

$$p_\gamma(\gamma) = \frac{(1+q^2)\gamma}{2q\bar{\gamma}}\, e^{\frac{-(1+q^2)^2\gamma}{4q^2\bar{\gamma}}}\, I_0\left(\frac{(1-q^4)\gamma}{4q^2\bar{\gamma}}\right), \ \ \gamma \geq 0 \tag{1}$$

Here, $I_0(.)$ represents the modified Bessel function of the first kind of zeroth-order. Nakagami-q fading parameter is represented as q. The range of the fading parameter is from 0 to 1. And γ is the instantaneous SNR and $\bar{\gamma}$ is the average SNR. When q=0, it is one sided Gaussian fading and for q=1, it becomes Rayleigh fading.

III. System Model

In single-input single-output (SISO) wireless communication system, both the transmitter and the receiver are equipped with single transmitting and single receiving antenna respectively.

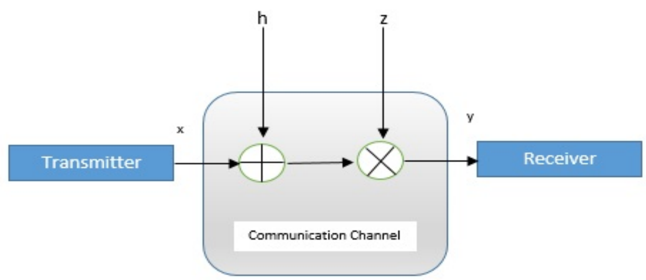

Fig. 1. System Model for Nakagami-q Fading SISO Wireless Channel.

The SISO system model for this work is shown in Fig. 1. For this study, let us consider Pt as transmitted signal power and let us also consider at the receiver end the received signal being corrupted by AWGN (additive white Gaussian Noise) also the transmission is carried over Nakagami-q fading channel. As described in [12] the received signal vector can be expressed as,

$$r = hx + z \tag{2}$$

Here, h indicating a vector that defines the channel gains from transmitter to the receiver antenna, x indicates the transmitted signal and z is a vector of zero mean complex AWGN. For SISO wireless communication systems, [13] states that, Shannon channel capacity is the highest reciprocated information between the transmitted signal and the received one and the capacity can be illustrated as,

$$C = Wlog_2(1 + \rho) \tag{3}$$

Here, $\rho = \dfrac{P_t}{\sigma^2}$ is the transmitted signal to noise ratio while W indicates the transmission bandwidth. As said in [10] and [14], the channel is power restricted in the perception that, $p_t = E\{|x|^2\}$ where the expectation operator is denoted by E{.} that is evaluated over the probability distribution function (pdf) of channel gain matrix, h.

For low SNR regime, using small argument limit approximation as described in [15], the zeroth-order modified Bessel function of the first kind can be approximated as $I_0 \approx 1$.

Using the above approximation the distribution in (1) becomes,

$$p_\gamma(\gamma) = \frac{(1+q^2)\gamma}{2q\bar{\gamma}} e^{\dfrac{-(1+q^2)^2\gamma}{4q^2\bar{\gamma}}}, \quad \gamma \geq 0 \tag{4}$$

Eq. (4) is the Nakagami-q distribution under small limit argument approximation for low SNR regime. Eq. (4) becomes Rayleigh fading distribution if the fading parameter is set q=1.

For high SNR regime, the derivation of the expression for the Nakagami-q distribution using large argument approximation is done. According to [16], the zeroth order modified Bessel function can be written as,

$$I_0(rt) \approx \frac{e^{rt}}{\sqrt{2\pi rt}}, \quad rt >> 1 \tag{5}$$

So, using this large argument approximation for Eq. (1), the zeroth order modified Bessel function of the Nakagami-q distribution becomes,

$$I_0\left(\frac{(1-q^4)\gamma}{4q^2\bar{\gamma}}\right) \approx \frac{e^{\dfrac{(1-q^4)\gamma}{4q^2\bar{\gamma}}}}{\sqrt{2\pi\dfrac{(1-q^4)\gamma}{4q^2\bar{\gamma}}}} \tag{6}$$

Nakagami-q distribution given in Eq. (1) using this above approximation becomes,

$$p_\gamma(\gamma) = \frac{(1+q^2)\gamma}{2q\bar{\gamma}} e^{\dfrac{-(1+q^2)^2\gamma}{4q^2\bar{\gamma}}} \frac{e^{\dfrac{(1-q^4)\gamma}{4q^2\bar{\gamma}}}}{\sqrt{2\pi\dfrac{(1-q^4)\gamma}{4q^2\bar{\gamma}}}}, \quad \gamma \geq 0 \tag{7}$$

To simplify Eq. (4) and (7) let us consider

$$a = \frac{1+q^2}{2q\bar{\gamma}}, b = \frac{(1+q^2)^2}{4q^2\bar{\gamma}} \; and \; n = \frac{1-q^4}{4q^2\bar{\gamma}} \tag{8}$$

Using the (8) simplifications, Eq. (4) becomes,

$$p_\gamma(\gamma) = a\gamma \; e^{-b\gamma}, \quad \gamma \geq 0 \tag{9}$$

And using the (8) simplifications Eq. (7) becomes,

$$p_\gamma(\gamma) = a\gamma \; e^{-b\gamma} \frac{e^{n\gamma}}{\sqrt{2\pi n\gamma}}, \quad \gamma \geq 0 \tag{10}$$

Eq. (10) represents the Nakagami-q distribution for high SNR regime under large argument approximation.

Eq. (9) and (10) are considered as Nakagami-q distribution for low SNR and high SNR regimes, respectively.

IV. Capacity Calculation

In this section the calculation of the capacity for Nakagami-q fading SISO channels is done for low SNR regime and high SNR regime. The capacity of this system is obtained by using Eq. (3),

$$C = \int_0^\infty p_\gamma(\gamma) log_2(1+\rho\gamma) d\gamma \tag{11}$$

For low SNR regime substituting Eq. (9) into Eq. (11), the capacity becomes,

$$C = \int_0^\infty a\gamma \;\; e^{-b\gamma} * log_2(1+\rho\gamma) d\gamma \tag{12}$$

and substituting Eq. (10) into Eq. (11), the capacity for high SNR regime becomes,

$$C = \int_0^\infty a\gamma \;\; e^{-b\gamma} \frac{e^{n\gamma}}{\sqrt{2\pi n\gamma}} * log_2(1+\rho\gamma) d\gamma \tag{13}$$

Mathematica [17], an advanced technical computing system is to explicate and validate Eq. (12) and (13) in order to analyze the data rate limit of this in high and low SNR regimes.

Using Eq. (12) the capacity of the low SNR regime results in,

$$C_{LSR} = \frac{a}{\rho^2 Log[2]} \left(G_{2,3}^{3,1}\left(\frac{b}{\rho} | \begin{smallmatrix} -2, & -1 & \\ -2, & -2, & 0 \end{smallmatrix}\right)\right) \tag{14}$$

if Re[b] $>$ 0 and Re[ρ] $>$ 0, where $G_{p,q}^{m,n}(x|\begin{smallmatrix} a_p \\ b_q \end{smallmatrix})$ is the Meijer G-function and C_{LSR} is the capacity of low SNR regime.

And using Eq. (13) the capacity of the high SNR regime results in,

$$C_{HSR} = \frac{ae^{\frac{-n}{\rho}}}{(2\sqrt{2}(b-n)^{3/2}\sqrt{n} \;\; \rho Log[2])}$$

$$\Bigg(\Big(-2e^{n/\rho}\rho + e^{n/\rho}0.577216 \;\; \rho + 2e^{b/\rho}\sqrt{b-n}\sqrt{\rho}\sqrt{\pi}$$
$$-e^{n/\rho}\rho\pi \;\; (Erfi[\frac{\sqrt{b-n}}{\sqrt{\rho}}])$$
$$+2e^{n/\rho}(-b+n)(({}_2F_2)(1,1;\frac{1}{2},2;\frac{b-n}{\rho})) + e^{n/\rho}\rho Log[4]$$
$$+e^{n/\rho}\rho Log[b-n] - e^{n/\rho}\rho Log[\rho]\Big)\Bigg) \tag{15}$$

if Re [b-n]>0, where 0.577216 is the “EulerGamma” which is a mathematical constant and Erfi (x) is the imaginary error function and ${}_pF_q$ (a;b;z) is the hypergeometric function and the generalized form is given by HypergeometricPFQ$[\{a_1,\ldots,a_p\},\{b_1,\ldots,b_q\},z]$ and C_{HSR} is the capacity of high SNR regime..

In the next section the plotting of Eq. (14) and (15) are done for some certain values of fading parameter, average SNR, instantaneous SNR and the analyses of the data rate limit are presented also.

V. Capacity Analysis

This analysis section is divided into two subsections. Behavior of capacity with respect to the instantaneous SNR and the fading parameter respectively is presented here and comparison of the capacity behavior for low SNR regime and high SNR regime is done in this section.

A. Data Rate Limit with Respect to Instantaneous SNR

First, plotting of the capacity vs instantaneous SNR for low SNR regime is done then the next is potted which is capacity vs instantaneous SNR for high SNR regime and at last comparison of both the low and the high SNR regime scenarios is done. Following Fig. 2 presents the capacity behavior with respect to instantaneous SNR for low SNR regime.

In Fig. 2 the correctness of Eq. (14) is verified which is derived from Eq. (12) by plotting Eq. (14) and Eq. (12) together. The same values are used for Eq. (12) as in Eq. (14).

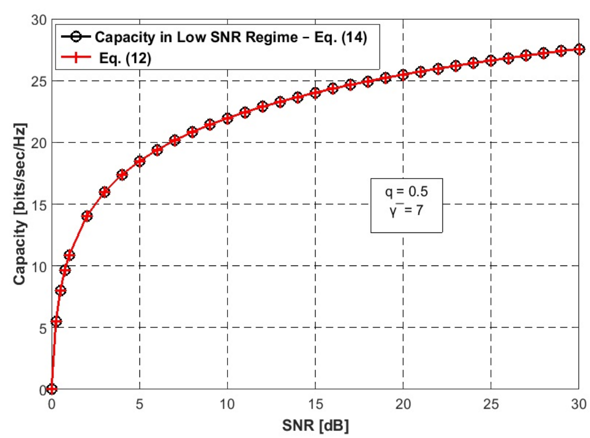

Fig. 2. Capacity [bits/sec/Hz] for low SNR regime with respect to instantaneous SNR [dB].

It can be seen in Fig. 2 that Eq. (14) is the accurate derivation of Eq. (12) as both the equations generate the exact same curve for the exact same values.

From Fig. 2 it is found that capacity of this Nakagami-q fading SISO system is increasing along with the increasing instantaneous signal to noise ratio.

Fig. 2 represents the capacity of this system with fading parameter q = 0.5, and average signal to noise ratio = 7. In this scenario capacity at 1 dB is 10.8631 bits/sec/Hz and as the capacity increases with the increasing of instantaneous SNR, the capacity at 30 dB is found 27.5641 bits/sec/Hz.

Fig. 3 presents the capacity behavior with respect to instantaneous SNR for high SNR regime.

As done for the previous low SNR scenario, the verification of the correctness of Eq. (15) is also done which is derived from Eq. (13) by plotting Eq. (15) and Eq. (13) together using same values for Eq. (13) as in Eq. (15) for high SNR scenario in Fig. 3.

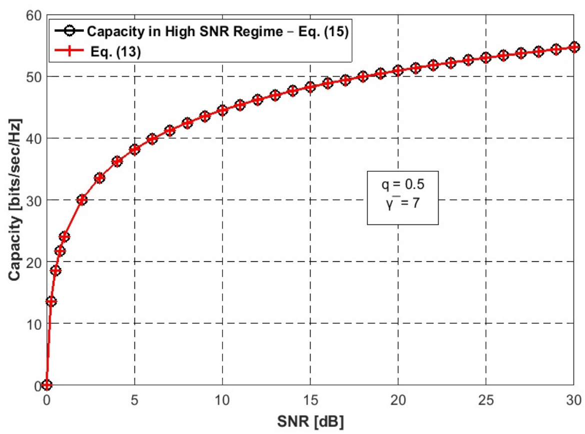

Fig. 3. Capacity [bits/sec/Hz] for high SNR regime with respect to instantaneous SNR [dB].

The justification of Eq. (15) as the accurate derivation of Eq. (13) can be seen in Fig. 3 as both the equations produce the exact same curve for the exact same values.

From Fig. 3 it is also found that in high SNR regime capacity of this Nakagami-q fading SISO system is increasing along with the increasing instantaneous signal to noise ratio.

Fig. 3 represents the capacity of this system with fading parameter q = 0.5, and average signal to noise ratio = 7. In this scenario capacity at 1 dB is 24.0783 bits/sec/Hz and the capacity at 30 dB is found 54.66 bits/sec/Hz.

Now the comparison of both the high and low SNR regime capacity is done with the same value of fading parameter q = 0.5, and average signal to noise ratio = 7. Fig. 4 presents the capacity of this system in both high and low SNR regimes with respect to instantaneous SNR.

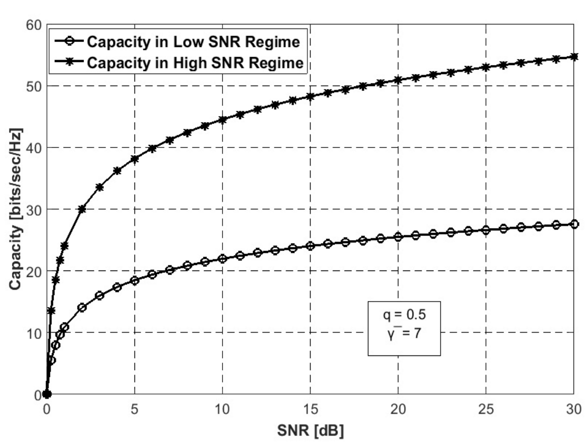

Fig. 4. Capacity [bits/sec/Hz] for both low and high SNR regimes with respect to instantaneous SNR [dB].

It is found from Fig. 2 and Fig. 3 that for both low SNR and high SNR regimes capacity of this system is increasing along with the increasing instantaneous signal to noise ratio. From Fig. 4 it can be stated that the capacity of this system has a higher increasing rate in high SNR regime than that of the low SNR regime.

In this scenario capacity at 1 dB is 10.8631 bits/sec/Hz for low SNR regime and 24.0783 bits/sec/Hz for high SNR regime and the capacity at 30 dB is 27.5641 bits/sec/Hz for low SNR regime and 54.66 bits/sec/Hz for high SNR regime. There is about 90.3197% increase of capacity for the range of 0 to 30 dB SNR in high SNR regime than the low SNR regime.

So, it can be said from the above analyses is that this system has higher data rate in high SNR regime than the data rate of the low SNR regime.

B. Data Rate Limit with Respect to Fading Parameter

In this subsection, plotting of the capacity vs fading parameter for low SNR regime is done first then moving to the next regime which high SNR regime and at last, like the previous subsection a comparison is presented of both the low and the high SNR regime scenarios.

Fig. 5 presents the capacity behavior with respect to fading parameter for low SNR regime.

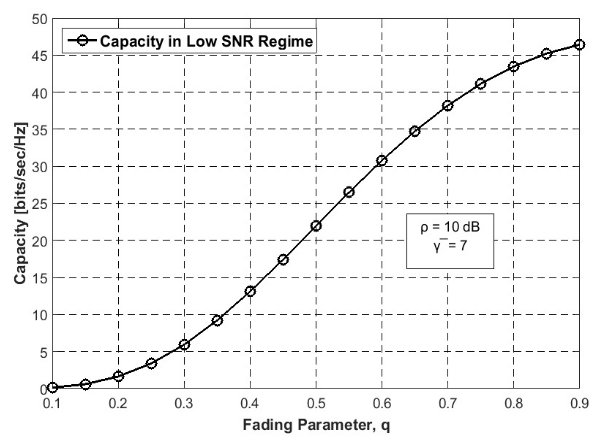

Fig. 5. Capacity [bits/sec/Hz] for low SNR regime with respect to fading parameter, q.

From above Fig. 5 it is found that capacity is increasing along with the increasing fading parameter, q. Up to 0.2 value of fading parameter there is a small increase in capacity and for the value of fading parameter after 0.2 up to 0.9 the increase is logistic.

Fig. 5 represents the capacity of this Nakagami-q fading SISO system with instantaneous SNR = 10 dB, and average signal to noise ratio = 7. In this case capacity at q = 0.1 is 0.133391 bits/sec/Hz and as the capacity increases with the increasing of fading parameter, the capacity at q = 0.9 is found 46.4261 bits/sec/Hz.

Fig. 6 represents the capacity behavior with respect to fading parameter for high SNR regime.

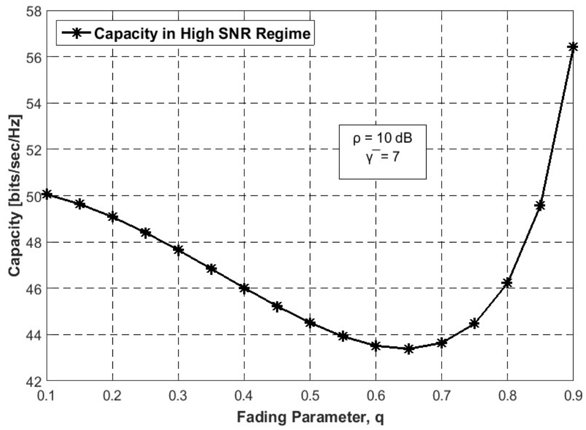

Fig. 6. Capacity [bits/sec/Hz] for high SNR regime with respect to fading parameter, q.

From Fig. 6 it is found that in high SNR regime capacity of this Nakagami-q fading SISO system has a different characteristics than that of the low SNR regime. The capacity in this high SNR regime is first decreasing along with the increasing fading parameter, q, starting from q = 0.1 up to q = 0.65. And from q = 0.66 up to q = 0.9 there is exponential increase of capacity.

Fig. 6 presents the capacity of this system with instantaneous SNR = 10 dB, and average signal to noise ratio = 7. In this scenario capacity at q = 0.1 is 50.0579 bits/sec/Hz, capacity at q = 0.65 is 43.3829 bits/sec/Hz and the capacity at q = 0.9 is found 56.4169 bits/sec/Hz.

And now, comparison of both the high and low SNR regime capacity is done with the same value of instantaneous SNR = 10 dB, and average signal to noise ratio = 7. Fig. 7 presents the capacity of this system in both high and low SNR regimes with respect to fading parameter, q.

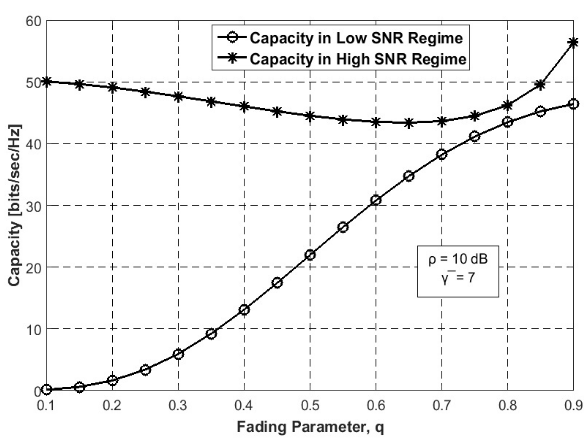

Fig. 7. Capacity [bits/sec/Hz] for both low and high SNR regimes with respect to fading parameter, q.

In Fig. 7, it is found from the comparison that the data rate in this case is higher in high SNR regime as the capacity with respect to the fading parameter has a higher value for the high SNR regime than the capacity of this system in low SNR regime. But it is also found that the capacity growth is consistent in low SNR regime than in high SNR regime as the capacity in high SNR regime is decreasing first up to a certain value of fading parameter and then it is increasing rapidly but in low SNR regime capacity increases logistically with the increasing of fading parameter.

There is no point of intersection found for capacity in Fig. 6. The separating value of capacity for this case is 43.4795 to 46.2262 bits/sec/Hz.

VI. Conclusion

In this paper, study of the data rate limit in both high and low SNR regime for Nakagami-q fading SISO wireless channel is discussed. For this the novel analytical expressions for the capacity of both the high and the low SNR regimes for this system using small limit and large limit argument approximation respectively are derived. This study presented in depth capacity analyses for both low and high SNR regimes. In this study, it is found that data rate of high SNR regime is better than low SNR regime as the capacity with respect to the instantaneous SNR for the system has a higher value in high SNR regime. It is also found that the capacity with respect to the fading parameter has a higher value in the high SNR regime but there is a noticeable fluctuation in this case as there is a notable decrease up to some point and after that the growth is exponential and in low SNR regime the capacity growth is logistic.

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DeepScratch: Scratch Programming Language Extension for Deep Learning Education

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***Abstract*—Visual programming languages make programming more accessible for novices, which open more opportunities to innovate and develop problem-solving skills. Besides, deep learning is one of the trending computer science fields that has a profound impact on our daily life, and it is important that young people are aware of how our world works. In this study, we partially attribute the difficulties novices face in building deep learning models to the used programming language. This paper presents DeepScratch, a new programming language extension to Scratch that provides powerful language elements to facilitate building and learning about deep learning models. We present the implementation process of DeepScratch, and explain the syntactical definition and the lexical definition of the extended vocabulary. DeepScratch provides two options to implement deep learning models: training a neural network based on built-in datasets and using pre-trained deep learning models. The two options are provided to serve different age groups and educational levels. The preliminary evaluation shows the usability and the effectiveness of this extension as a tool for kids to learn about deep learning.**

***Keywords*—Deep learning; visual programming languages; programming education; formal language definitions; neural networks**

I. Introduction

Programming nowadays is considered an essential skill and has been introduced in a novice level for different ages. Moreover, visual programming languages make programming more accessible for young people, which open more opportunities to innovate and explore. Scratch [1]; a visual programming environment developed by MIT, is one of the most popular block-based visual programming languages that allows users to create interactive and media-rich projects. On the other hand, deep learning is one of the trending computer science fields during the last years, and it acquired interest and focus in many different fields. Deep learning has a profound impact on our daily life and it is important that young people are aware of how our world works. However, it is not an easy task to understand the concepts of a deep learning as it requires deep understanding of mathematics and calculus. Understanding and applying deep learning requires spending hundreds of hours learning and debugging code, which is mostly frustrating for juniors.

The aim of this research is to extend the vocabulary of Scratch programming language to help young people designing and implementing deep learning applications. Deep learning has a profound impact on society. It has many applications in finance, healthcare, customer experience, weather prediction, etc. Nowadays, it is important that kids are aware of how the world works and understand the capabilities of deep learning. This paper presents DeepScratch, a new programming language extension to Scratch that provides powerful language elements to facilitate deep learning concepts to allow kids and high schoolers to understand and develop deep learning applications. This research is an extension of the paper: "Extending Scratch: New Pathways into Programming" [2].

DeepScratch provides two options to implement deep learning models: training a neural network based on built-in datasets, or using pre-trained deep learning models. The two options are provided to serve different age groups and educational stages.

This paper introduces two main contributions:

- Extend the vocabulary of Scratch visual programming language to enable developing deep learning applications using Scratch, which opens an opportunity for researchers to continue and expand our work.
- A tool for educators to teach kids basic deep learning concepts (different neural networks architectures, hyper-parameters tuning, and classification metrics).

Being able to build deep learning application with visual programming language should be very useful for kids. In addition, high schoolers who are interested in deep learning can implement various applications in an environment that does not require understanding of programming, mathematics, and calculus concepts. We believe that this work will help in closing the knowledge gap between educators and students, thus enabling them to explain machine learning concepts in an environment that are more suitable for novice programmers. Our preliminary evaluation showed significant effects of using DeepScratch on students' understanding of deep learning.

The rest of this paper is organized as follows: Section II introduces the background. Section III presents previous studies that proposed related applications. Section IV introduces the methodology followed in this study. Section V describes the syntactical definition (grammar) used for DeepScratch extension. Section VI presents the lexical definition of DeepScratch by explaining the functionalities of the extended vocabulary.

Section VII demonstrates some examples of simple programs developed using DeepScratch. Section VIII discusses the significance DeepScratch and describes the conducted evaluation process to ensure the functionality and the usability of the developed extension. Finally, the conclusion is presented in Section IX.

II. Background

Visual programming languages allow users to develop programs by manipulating elements graphically instead of writing a program as a text. These languages can potentially allow young people to acquire the computational concepts more easily by reducing unnecessary syntax and facilitating the use of dragging and snapping the command blocks. With such features, these frameworks can help reduce the cognitive load on novices by allowing them to focus on the logic and structures of a program rather than worrying about the syntax and the mechanism of coding [3].

There is a rich history of different visual programming tools designed for novices comprehensively surveyed in [4]. AgentSheets by Repenning and Sumner [5] is a tool that introduced the blocks programming in 1995 to create games and simulations. Their work marked a substantial step in the field of visual programming language [6]. Several block-based programming language were designed after AgentSheet, such as Squeak eToys, Alice, and Scratch [6].

Scratch was created by MIT Media Lab's Lifelong Kindergarten Group in collaboration with Yasmin Kafai's group at UCLA [7]. The main idea for Scratch was inspired by LEGO bricks, as Scratch research team worked closely with LEGO company [8]. Scratch grammar was converted to a programming blocks which represent the bricks in the LEGO. To create a program, users need to simply tinker the blocks together [8]. Thereafter, in the third version of Scratch, they collaborated with Blockly, a project developed by Google. Blocks are end-user composable, editable, and can be arranged geometrically to represent tree structure and to define syntax [9]. The previous four keys form the properties of a highly accessible visual programming paradigm combined by the AgentSheets [6]. According to [6], Scratch and Blockly adopted these properties to be in their core, and became the popular blocks programming language. Fig. 1 demonstrates how a Python code block looks like in Scratch programming language.

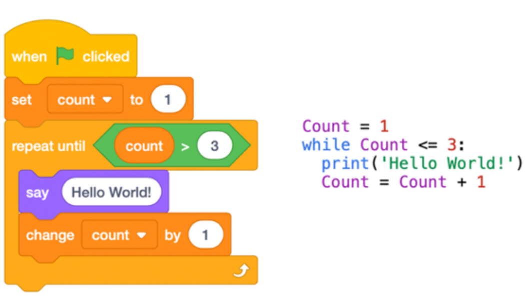


Fig. 1. Scratch blocks and its equivalent Python code

In 2015, Scratch team presented the scratch extension system to enable programmers to innovate on the language itself by extending it [2]. In addition, "enabling learners with a diverse set of interests to engage in programming with Scratch by opening up a number of previously unavailable pathways, through new domain-specific programming primitives" [2]. However, deep learning development is not supported yet by the original Scratch language or as an extension to this language.

Deep learning is a sub-field of machine learning dealing with algorithms that are similar to how nervous system structured, where each neuron is connected and passing information to each other [10]. Deep learning aims to learn complex relationships among data that make out meaningful results, and predict from multiple applications.

III. Related Work

Machine learning, deep learning, and data science are Key topics that are not yet addressed much in the existing tools dedicated to youths. These are advanced fields for novices, but becoming essential to learn for the world we live in today and the one we will experience in the future.

Few systems have been designed to provide a straightforward and simple understanding of data science and machine learning geared towards kids or high school students. For Data Science applications, *Scratch Community Blocks* [11] is a system that enables children to programmatically analyze and visualize data about their participation in Scratch, and learn how to reason about complex information visualizations. *DataSnap* [12] is an extension to the block-based language *Snap* which can fetch and analyze data from online sources.

Similarly, Machine Learning is available as an education tool using different programming languages. *Machine Learning for Kids* project [13] brings in the power of the IBM Watson engine by presenting Machine Learning Building Blocks such as image recognizers and text classifiers that can then be imported to a Scratch program. Ken Kahn [14] has created resources to allow beginners to create AI applications such as speech synthesis, speech recognition, and image recognition, in the block-based language Snap.

Teachable Machine [15] is a web-based tool developed by Google that allows users to train and test machine learning model without writing code. However, Teachable Machine is a very abstract tool and does not introduce basic machine learning concepts such as hyper-parameters, different algorithms, and evaluation metrics. Our research aims to introduce an extension of Scratch programming language that covers more advanced machine learning concepts, specifically, deep learning concepts.

Our literature review revealed the need to develop an environment that supports teaching kids different machine learning concepts including learning about different neural network architectures, optimizing a neural network, and performing hyper-parameter tuning. Previous studies tackled this topic in a more abstract level, allowing the kids to build machine learning applications without learning the underlying processes and concepts of the machine learning models.

IV. Methodology

The Incremental Model is used to develop the DeepScratch extension. This model is based on developing an initial component, which usually includes the fundamental requirements. After evaluating the initial component, several other components are added until the software is fully developed. The Incremental Model can be Plan-Driven or Agile. In this research, the Agile approach is adopted as it does not require a pre-planned set of increments. Agile model makes the development process flexible and cost-efficient to adapt to the changes [16]. Since this is a research-based project, and research is expected to be exposed to changes; the Incremental Agile Model is selected.

A. Process Activities

- **Software specification:** It is the process of understanding and identifying the required services for the software [16]. In general, the specifications of this extension include implementing the following features:
  - Input methods: since deep learning applications require a lot of data that need to be labeled, built-in datasets are available in DeepScratch, which are the *Iris* and *MNIST* data sets.
  - Neural networks: Dense, RNN, and CNN.
  - Predicting new data.
  - Evaluation metrics: loss function (cross-entropy), training accuracy, and testing accuracy.

- **Software design and implementation:** It is the process of converting the software specifications into executable software. However, this activity might include some refinements on the software specification [16].
  The design of our extension follows the design principles established by Scratch. These design principles aim to help the developers to design simple and easy to use language that encourages users to quickly explore and experiment with the language functionalities [9]. Scratch allows extending the programming language using JavaScript [2]. Therefore, *TensorFlow.js* [1]; a library for deep learning in JavaScript will be used for the implementation.

- **Software validation:** Verification and validation is applied to each increment based on its requirements. Once the software is complete, a full system functionality testing will be applied as the final stage of the testing process. Functionality testing is used to ensure that the software meets its specifications and is ready to be published [16].
  Moreover, usability testing will be conducted by a focus group of kids to validate the extension's ease of use.

- **Software evolution:** As this is a research-based project, this step is considered as the future work.

V. Syntactical Definition

Any visual programming language (VPL) is characterized by two main elements: a grammar (syntactical definition) and a vocabulary (lexical definition) [17]. Together they define the set of concepts that can be expressed with the programming language. The grammar of VPL is described by the visual metaphor, such as blocks and wires. Whereas the vocabulary is the collection of blocks, icons, or other components that allow a programmer to express concepts.

This section explains the grammar of Scratch, which will be the base of the proposed extension. In practice, to run a text-based program, a program takes the program as an input and extracts lexemes (sequence of characters in the source program) and tokens (categories of lexical units). Then, following the context-free grammar, a program takes the tokens and creates a parse tree. Since Scratch is not a text-based language, the interpreter does not need to tokenize and parse the program.

The grammar of a text-based language is usually defined by metasyntax notation such as EBNF (Extended Backus–Naur Form). However, the grammar of Scratch is described by defining blocks of different shapes representing expressions, statements, and control structures. These shapes are fitting together in only syntactically-correct ways. This eliminates syntax errors by setting geometric relations rules (containment, horizontal/vertical concatenations, etc.) to connect the blocks together [18].

There are six shapes of Scratch blocks: *Hat* (trigger blocks), *Stack* (command blocks), *Boolean*, *Reporter* (function blocks), *C* (control structure), and *Cap* [1]. Each shape has its own function and properties [1], [18]. In our work, we will use the Stack and Reporter blocks to build Scratch-based deep learning models. The Stacks (command blocks) are like the statements of a text-based language, they are shaped with a notch at the top and a bump on the bottom, so that blocks can be placed above and below them to create a sequence of commands [1]. Whereas Reporters (function blocks) hold values (Number or String) as constants or in a variable. They can be used as arguments to commands to build expressions [1].

According to [2], the affordances of the Scratch extension system allow for extending the vocabulary rather than the grammar, and thus, DeepScratch extends the language by augmenting the vocabulary. The following section will describe the extended vocabulary in detail.

[1] https://www.tensorflow.org/js/

VI. Extension's Vocabulary

There are 119 blocks working as the standard Scratch vocabulary (not including extensions) [18]. The syntax of some of these blocks is illustrated in [18]. This section demonstrates the vocabulary of DeepScratch, which are custom programming blocks written in JavaScript. While adhering to Scratch grammar, each extension block is mapped to a JavaScript script that gets invoked through a "bridge" layer implemented within Scratch. In addition, *Tensorflow.js* library is utilized for building and executing deep learning models that run in a web browser and in the Node.js.

Our Scratch extension will provide the users with two options to implement deep learning models. The first option enables the user to train the model, by giving the ability to choose the dataset, the architecture of the neural network, and a variety of hyper-parameters. Dense, RNN, and CNN are the architectures of neural networks available for training in DeepScratch. The other option allows the user to run pre-trained models that can be used to predict new data. DeepScratch will support different pre-trained models offered by TensorFlow from Google, such as object detection model. Sections VI-A and VI-B describe these two options in detail.

The complete vocabulary of DeepScratch is represented in Tables I and II. The DeepScratch blocks can be combined with other Scratch blocks to build an application, such as adding "say" block by Scratch to present the prediction result. Lastly, to save our work and for further development, we made our code available through GitHub[2].

A. Training Deep Learning Model Blocks

Training a deep learning model needs expertise in certain programming languages. This process is simplified through DeepScratch blocks that bind together as in Fig. 1.

Each machine learning program consists of three main stages: pre-processing data, training a model, and predicting new data. Preparing and pre-processing data can be complicated and frustrating for young people, and moreover, it's not in the scope of how machine learning models work. Hence, the proposed extension provides built-in datasets that are ready to be trained. These datasets are the popular Iris[3] and MNIST[4] datasets.

In DeepScratch, the first step in training a machine learning model is to choose which combination of a dataset and a neural network model to use. The available NN models are Dense, RNN, and CNN. Each model can be tweaked by changing some hyper-parameters specific to that model. For example, in the CNN model, the user can change the batch size and set the number of epochs as optional hyper-parameter. During training, the user will be able to monitor how the model optimizes by displaying accuracy and loss values. Once the training is done, the user will be able to check the accuracy on the testing data. This way, the user can learn how different hyper-parameters settings can affect the performance of the model. In Fig. 2, the user used the *train Dense* block to train the Iris dataset using a Dense model with two hidden layers and 20 epochs. If the user trains the model without setting the optional block (*number of epochs*), it will take the default value: 10 epochs. At last, the user used the basic *say* block to display the testing accuracy once the training is done.

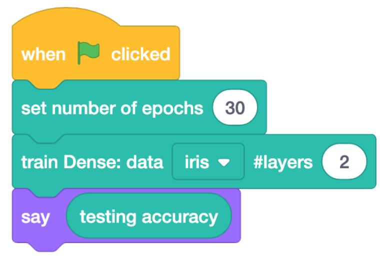


Fig. 2. Training Iris Data using Dense Model

After training the model, the user can use *predict* block to classify new data. There are different predict blocks to cover the variety of datasets that have been trained. The user needs to enter new data, and based on the input data, he/she will pick the suitable predict block. Fig. 3 illustrates an example of using *predict iris* block for the Iris data. The result of this prediction and the training performance is presented in Fig. 4. Fig. 5 illustrates all the logically possible combinations of the blocks.

The blocks used for training and prediction are implemented using the *Stack* blocks from Scratch. To present to the user how the model optimizes during training; *Reporter* blocks were used to display the training accuracy, testing accuracy, and loss values during training (Fig. 4).

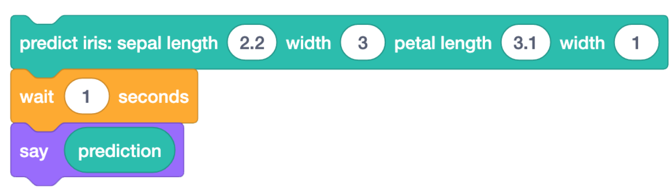


Fig. 3. Predicting Iris Data

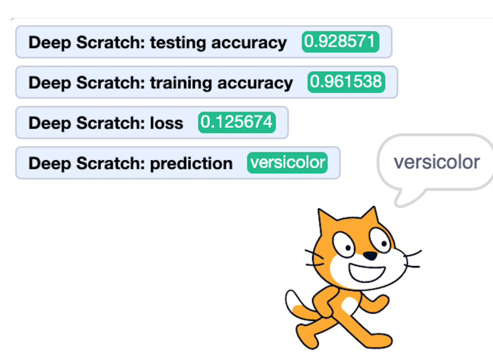


Fig. 4. Result of Training a Neural Network in DeepScratch

[2]https://github.com/Noufst/DeepScratch
[3]https://archive.ics.uci.edu/ml/datasets/Iris
[4]http://yann.lecun.com/exdb/mnist/

TABLE I. VOCABULARY OF DEEPSCRATCH (STACK BLOCKS)

ID	Block	Description	Parameters		Pre-condition
			Name	Data Type	
S1	set number of epochs 10	Change the number of epochs	N/A		None
S2	train Dense: data iris #layers 2	Train Dense neural network	Dataset #Layers	Drop down list Number	None
S3	train RNN: data iris	Train RNN neural network	Dataset	Drop down list	None
S4	train CNN: data MNIST batch size 320	Train CNN neural network	Dataset Batch size	Drop down list Number	None
S5	predict iris: sepal length 0 width 0 petal length 0 width 0	Predict new Iris data.	Sepal length Sepal width Petal length Petal width	Number Number Number Number	Should be stacked anywhere under Train Dense block (2) with Iris data selected
S6	predict hand-written digit from MNIST	Predict new hand written image.	N/A		Should be stacked under the Camera block (S8) with On selected.
S7	detect objects	Detect objects from the current video frame.	N/A		Should be stacked under the Camera block (S8) with On selected.
S8	turn video off	Turn on/off the camera	On/Off	Drop down list	

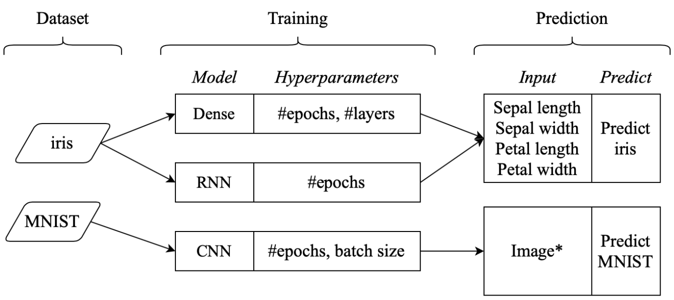
TABLE II. VOCABULARY OF DEEPSCRATCH (REPORTER BLOCKS)

ID	Block	Description
R1	training accuracy	Holds the value of the accuracy during training. The value gets updated after each epoch.
R2	loss	Holds the value of the loss during training. The value gets updated after each epoch.
R3	testing accuracy	Holds the value of the accuracy on the testing data. The value is set after the model training is complete.
R4	prediction	Holds the prediction value after running one of the prediction blocks (S5 or S6).
R5	object name 1	Holds the name of the detected object after loading the pre-trained model (S7) (the user can choose between three detected objects using the drop-down list if they exist).
R6	object correctness % 1	Holds the confidence percentage of the detected object (the user can choose between three detected objects using the drop-down list if they exist).
R7	object x position 1	Holds the x position for the detected object in the video frame (the user can choose between three detected objects using the drop-down list if they exist).
R8	object y position 1	Holds the y position for the detected object in the video frame (the user can choose between three detected objects using the drop-down list if they exist).

B. Pre-Trained Deep Learning Model Blocks

A pre-trained model is a model that is already trained on a large dataset, and can be used directly to predict new examples. Providing pre-trained model blocks in DeepScratch should be very useful for kids, as they will be able to build deep learning applications with a visual programming language. TensorFlow from google offers many pre-trained models; our extension will provide the object detection model, that localize and identify multiple objects from an image or a video.

In order to use the object detection model within DeepScratch, the user should drag the *detect objects* block and give permission to enable the video camera. Once the user turn the video camera on, it will be used as an input for prediction based on the object detection model. *detect objects* block will capture three objects as maximum from the current frame in the video. The detected objects have four outputs: object class, confidence score, and their position coordinates (x,y). Each output is presented in a reporter block with a drop-down list (1, 2 or 3) that represent the number of the detected object. The *object class* block recognizes the detected object and return its class (e.g. person, cell phone, tie, or bottle).



* Requires using "Turn Camera On" block

Fig. 5. Different Possible Combinations of Training and Prediction Blocks in DeepScratch

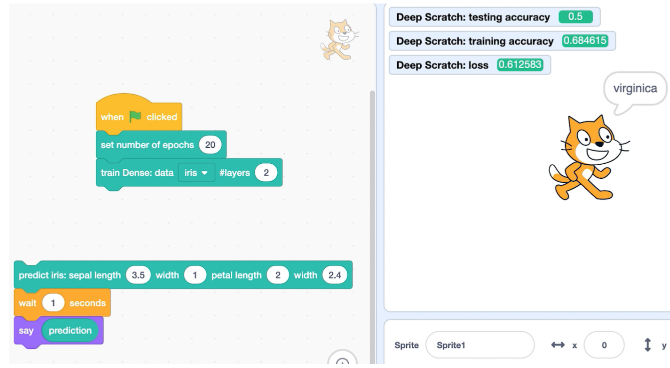


Fig. 6. Simple Program to Train and Predict Iris Data using Dense Neural Network

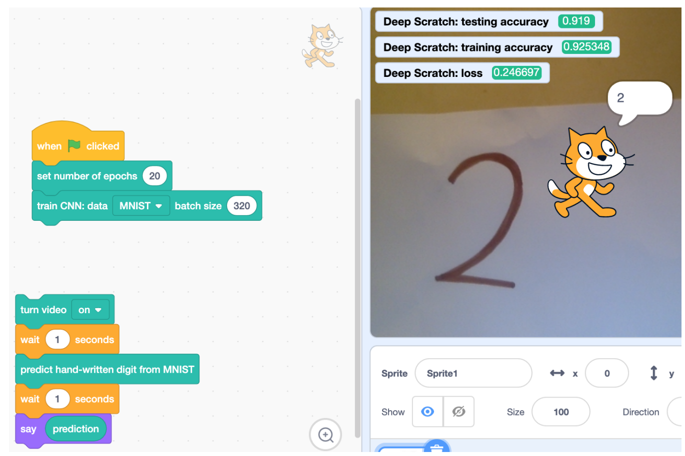


Fig. 7. Simple Program to Train and Predict Hand-Written Images using CNN Model

The confidence score indicates confidence that the object was genuinely recognised, and presented in the *object correctness* block. For the position coordinates, the video frame placed in Scratch stage deal with x and y as coordinates in Cartesian plane. The origin is the axes cross located in the center of the video frame, thus the coordinates will be in one of the four quadrants. However, the object detection model considers the upper right corner as the origin for x and y coordinates. Consequently, we convert the x and y that model returns to fit in the Cartesian plane to be returned by *X and Y positions* block, which will locate the position of the detected object in the video frame.

VII. Illustrative Examples

This section presents some examples of how DeepScratch can be used and utilized in combination with the basic Scratch blocks to build a variety of applications.

Fig. 6 demonstrates a simple program to train and predict Iris data. The left-hand side represents the program code (the blocks), where the right-hand side shows the output of the program.
The first set of blocks are used to set the number of epochs to 20, and to train a Dense neural network with two hidden layers. As the model is training, the user can observe how the accuracy and the loss values are being optimized after each epoch. Once the training is done, the accuracy of the testing data will be available to the user. The second set of blocks are used to build the prediction phase. Based on the values the user typed inside the *predict* block, the prediction (name of the iris) is presented to the user by utilizing the basic *say* block.

In Fig. 7, the user built a program that detects hand-written numbers by training the MNIST data. For the training step, a CNN model is trained with 20 epochs and a batch size of 320. Similarly, training accuracy, loss, and testing accuracy values are available to the user. To predict a new image, the user must use the *turn video* block and show a picture of a hand-written number to the camera. After that, *predict* block captures the image, converts it to a tensor, and gives it to the model to generate the prediction to be displayed to the user.

The last example illustrates how a pre-trained model can be used to build a deep learning application. The program in Fig. 8 works as follows: First, the camera is turned on. Then, the model is loaded and a capture of the camera screen is passed to the model to detect objects. After that the sprite (the cat character) will *move* to the coordinates of the first detected object and *say* its name. At last, after 5 seconds, the sprite will do the same for the second detected object. Fig. 9 demonstrates the output of the first and second detected objects.

VIII. Discussion and Preliminary Evaluation

In this section, we discuss how DeepScratch will contribute to educating kids about machine learning principles compared to the similar work highlighted in Section III. Additionally, we present the evaluation process design and the preliminary results.

Scratch Community Blocks [11] and *DataSnap* [12] aim to develop the programming and the analytical skills in preference to teaching kids the principles and the concepts of machine learning. *Machine Learning for Kids* [13], Kahn's and Winters's project [14], and *Teachable Machine* [15] are developed to teach kids how machine learning models work in abstract level. They provide a high-level overview of the machine learning pipelines. In contrast, **DeepScrach** is

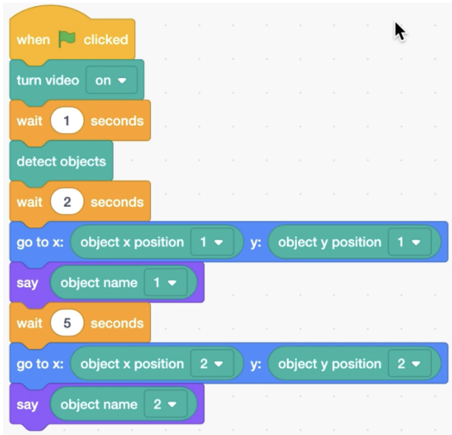


Fig. 8. Simple Program to Detect Object using the Pre-Trained Object Detection Model

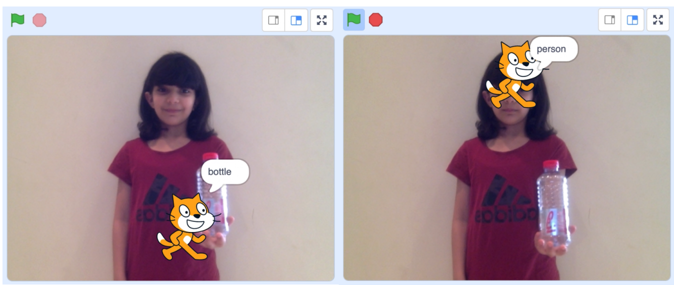


Fig. 9. Output of the Pre-Trained Object Detection Model

developed to promote teaching kids more technical skills that aim to pave the way for them to engage in more sophisticated concepts and models. The skills supported by DeepScratch are: learning about different deep learning architectures, how a model's performance is evaluated, and how to tune a model to produce a better performing model.

In order to evaluate DeepScratch extension, we conducted a full system functionality testing. Functionality testing is used to ensure that the software meets its specifications and is ready to be published. In addition, we conducted a usability study with a focus group of 5 students to validate the extension's ease of use. The plan was to conduct the user study in a school with more than 30 students; however, this could not be achieved as this research conducted during the COVID-19 curfew.

A. Functionality Testing

The functionality testing was conducted by constructing a test case for each vocabulary in DeepScratch. Each test case is described by input, pre-requisite, expected output, and actual output. If the actual output matches the expected output, the test case is considered as passed. In total, we constructed 16 test cases, all of them passed with the expected results.

B. Usability Testing

This section describes how the usability testing was designed, how the metrics were selected and measured, and the results of the usability evaluation process.

1) Usability Testing Design: A user study was conducted to inspect the usability of the proposed extension. As stated earlier, this research was conducted during the COVID-19 curfew which leads to a very limited number of participants. A preliminary experiment is conducted with a focus group of five students selected based on their availability. Participants were asked to perform two tasks to build \use deep learning networks.

Participants' sociodemographic characteristics (gender, age, spoken language) were recorded. Their ages ranged from 8 to 17 years (4 females, 1 male). In terms of their spoken language, all users were Arabic native speakers, 3 of them have intermediate English level and 2 are beginners. We interviewed the participants' to assess their level of familiarity with Scratch and deep learning on a 4-point scale (1 = not at all familiar, 4 = very familiar). The results show that all participants have basic experience of using Scratch and similar knowledge of deep learning concepts. Their description of "deep learning" concept was very similar, they described it as a way to imitates the way humans gain certain knowledge and to automate predictive analytic.

In order to measure the usability, a set of specific metrics should be used as a mean of the evaluation process. The International Organization for Standardization (ISO) defined usability as "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use" [19]. In other words, without measuring the *effectiveness*, *efficiency*, and *satisfaction*, usability evaluation cannot be achieved. The definitions of the usability metrics (according to ISO), and how each metric will be measured in our study are presented next.

- **Effectiveness:** Measures the completeness and accuracy of the goals achieved by the users. In this study, the effectiveness will be measured by the number of the completed tasks. Each task will be marked as: completed or not completed.

- **Efficiency**: Measures the expended resources to achieve the user's goals in relation to the level of effectiveness. Based on the goal of this extension, the temporal (time-based) efficiency will be measured, which is the effectiveness divided by the time used to complete the tasks.

- **Satisfaction**: Measures the extent to which the users are comfortable, and the positive attitudes of using the extension. As a mean to measure the satisfaction, questionnaires were provided to the users to answer subjective questions about their satisfaction with using the extension.

2) Usability Testing Results: On the day of the experiment, participants received a printed form that briefly describes DeepScratch, and explains the details of two tasks, followed by a questionnaire to evaluate their experience.

We analyzed the data for all participants in accomplishing each task and answering the questionnaire. The three metrics were used as means of the evaluation process (effectiveness, efficiency, and satisfaction). For the effectiveness, the total number of completed tasks is divided by the total number of undertaken tasks. All the users completed the two tasks successfully in our experiment (i.e. the completion rate is 100%).

$$\text{Effectiveness} = \frac{\text{Number of completed tasks}}{\text{Total number of undertaken tasks}} \times 100\% \tag{1}$$

In order to examine the efficiency, we considered the *time-based efficiency*, which is the user effectiveness divided by the user time spent. Since our completion rate is 100%, all the user time spent will be considered in efficiency calculations, as shown in Table III. The average time that the user spends on both tasks is 6.18 minutes.
To calculate the time-based efficiency we applied the following equation:

$$\frac{\sum_{i=1}^{T}\sum_{j=1}^{U}\frac{u_{i_j}}{t_{i_j}}}{UT} \tag{2}$$

Where U equal to the number of users and T is the total number of tasks. Thus, Uij represents the result of task i by user j (Uij=1 when the user successfully completes the task, Uij=0 otherwise). Tij is the time spent by user j to complete task i. By applying the above equation, the overall efficiency is 0.37 tasks/minute. This infers that the DeepScratch is efficient and supports users in achieving their goals and tasks in minimal time. Furthermore, we can infer that implementing deep learning models using DeepScratch takes a considerable less time than implementing the same models with textual programming.

TABLE III. THE TIME SPENT BY USER IN EACH TASK IN MINUTES

Uesr	Task1	Task2
user 1	2.2	2.0
user 2	3.1	1.8
user 3	4.3	2.6
user 4	5.6	4.0
user 5	3.2	2.1

To measure the satisfaction, the questionnaire asked the participants to rate their experience with DeepScratch, in terms of usefulness and ease of use, along with their perceived knowledge of deep learning concepts. All participants reported that the applications were very easy to create, and supplemented their understanding of deep learning models. However, three students raised the need of translating the blocks into Arabic Language.

IX. CONCLUSION

In this paper, we presented the motivation and the design of DeepScratch; an extension to Scratch programming language. We explained how the system is designed to allow kids to engage with the concepts of deep learning -normally practiced only by expertise- in a simple and attractive way. We built this programming language extension in order to satisfy our goal of promoting new pathways to understand deep learning concepts and applications. This paper presented the implementation process of DeepScratch, and explained the functionality of the extended vocabulary. DeepScratch provided two options to implement deep learning models: training a neural network based on built-in datasets, and using pre-trained deep learning models. The two options are provided to serve different age groups and educational levels.

To inspect the functionality and the usability of the proposed extension, we conducted a full system functionality testing and a user study. Both methods revealed the effectiveness of the proposed extension, and the participants reacted positively to the experiment of DeepScratch. As this was a preliminary user study, the obtained results were encouraging. However, for more concrete results, it will be necessary to expand the experiment with a larger group of kids. Furthermore, future studies can extend DeepScratch to include more neural network architectures and different applications.

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Enhancing Disease Prediction on Imbalanced Metagenomic Dataset by Cost-Sensitive

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***Abstract*—Imbalanced datasets usually appear popularly to many real-world applications and studies. For metagenomic data, we also face the same issue where the number of patients is greater than the number of healthy individuals or vice versa. In this study, we propose a method to handle the imbalanced datasets issues by Cost-sensitive approach. The proposed method is evaluated on an imbalanced metagenomic dataset related to Inflammatory bowel disease to do prediction tasks. Our method reaches a noteworthy improvement on prediction performance with deep learning algorithms including a MultiLayer Perceptron and a Convolutional Neural Neural Network with the proposed cost-sensitive for Metagenome-based Disease Prediction tasks.**

***Keywords*—Cost-sensitive; imbalanced datasets; disease prediction; deep learning**

I. Introduction

The history of medicine is the struggle against the disease based on "one size fits all" strategy. In general, this strategy treats patients who have the same diseases in the same way but in several special cases, that may not be the best treatment for specific patients. Recently, tremendous headway has been proposed in personalized health care, also referred to as precision medicine or personalized medicine. Precision medicine incorporates the insights on environmental, behavioral factors, genome, or biology of a patient.

More specifically, the genetic profiles, and several personal records of the patients are analyzed for identifying the factors of a specific disease, the treatment and prevention can be applied to each patient. It does not only prevent the influence of side effects but also ensures better outcomes. Precision medicine demands to provide the right treatments to the right person at the right time. Furthermore, several studies reveal the contribution of microbiomes on health and disease are considered as a part of precision medicine [1], [2]. The human body contains trillions of bacteria and other microbes and these microbial communities have been examined whole-genome sequencing by the study namely The Human Microbiome Project (HMP) [3]. Metagenomic can be considered as an alternative approach for clarifying the relationship between microbial communities and host phenotype. Furthermore, the discovery of vast new genealogy of microbial life can be developed based in the analysis of 16rRNA sequences from the uncultured microorganisms which represent for the massive majority of creature [4], [5], [6]. Besides, leveraging metagenomic in personalized medicine might take care of many crucial issues [7], [8].

The metagenomic data analysis has created the opportunity for improving the algorithms for specific disease prediction but there are still challenge in computational methods and relatives. The real-world data collection encountered many difficulties and almost the collected datasets are imbalanced. Normally, in the field of metagenomics, the interesting classes have fewer samples than the others and the performance of predicting true label for interesting classes are extremely necessary and important. The cost of a misclassified majority class is usually lower in comparison with the cost of misclassified minority class [9]. The imbalanced ratio affects the performance seriously. Several classic classifiers tried to maximize the validation accuracy and bypass the sensitivity of each class.

II. Related Work

In the field of metagenomic analysis, data pre-processing is truly important and can improve predictive performance. The study [10] proposed a deep learning framework, namely DeepMicro to represent microbiome profiles effectively. Several auto-encoders and machine learning algorithms are used to transform from high-dimensionality of microbiome data into low-dimensional. However, there is still a challenge with meaningful and noisy information. To leverage the meaningful information, the meaningful information should be contained by the learned representation due to encoding of the properties of the input are depended on auto-encoders.

The limitations of data still challenge for several studies in metagenomics fields. The study [11] presented an approach for boosting the performance based on generated metagenomics data. The authors employed a Conditional Generative Adversarial Network (CGAN) to generate the samples which are very similar to the original samples. The predicting host phenotype performance has been improved by augmenting the training dataset. Data augmentation is a common technique to improve performance and generalization in machine learning [12]. Additionally, the authors in [13] also stated the performance of prediction can be able to boost by using Generative Adversarial Network (GAN) models. Nevertheless, selecting the best CGAN model is still a difficult task, the optimal model can be bypassed.

The study [14] presented a machine learning approach for diagnostic decisions. The predictive model is simple but gains a powerful score by computing the cumulative abundance of microbiome measurements. However, the performance of predictive models can be affected by data quantification problems. More specifically, the individuals and specific types of microbial ecosystems have a significant difference in microbial loads [15]. Furthermore, the model can select various sequencing depth can be over or underestimate less abundant taxa.

In this study, we propose a Cost-Sensitive method [16], [17] to handle the imbalanced datasets issue. Thereby, enhancing the performance on disease prediction task. Our contributions include the following:

- We present the considered datasets and handling imbalanced issues with the Cost-Sensitive method.
- The efficiency of the proposed methods is evaluated on three types of learning models including Multilayer Perceptron (MLP), and Convolutional Neural Network (CNN). The performance with the Cost-Sensitive method obtains better results for each learning model.

In the remaining of this study, we introduce the considered dataset in Section III. The learning algorithms and Cost-Sensitive are proposed in Section IV. Section V presents the compared performance of each learning model in cases of before and after applying the Cost-Sensitive method. We discuss and summarize the results in Section VI.

III. Imbalanced Datasets in Metagenomics

The proposed approach performance is evaluated on the Inflammatory Bowel Disease (IBD) dataset [18], more details are in Table I. The details of the considered datasets including the numbers of features, samples, patients, and several additional information.

Table I indicates that the number of samples and patients is widely large, it is a basic case of imbalanced datasets. Imbalanced datasets are relevant primarily in the context of a classification task where the class distribution is not uniform among the classes. The considered dataset contains 25 patients and 110 samples, the patient ratio of 0.23, and the ratio of the control of 0.77. Each sample or patient includes 443 discriminate features. Each feature reflects the proportion of a bacterial species existing in a sample's body.

The total value of all features (relative abundance of bacterial species) in one patient or a healthy individual is sum up to 1 (as shown in Equation 1):

$$\sum_{i=1}^{k} f_i = 1 \tag{1}$$

TABLE I. Details of Inflammatory Bowel Disease (IBD) Dataset.

Dataset	**IBD**
Features	443
Samples	110
Patients	25
Controls	85
Ratio of patients	0.23
Ratio of controls	0.77

```
OPERATION           DATA DIMENSIONS   WEIGHTS(N)   WEIGHTS(%)

   Input   #####      1  443
 Flatten   ||||| -------------------          0     0.0%
           #####        443
   Dense   XXXXX -------------------      28416    99.8%
           #####         64
   Dense   XXXXX -------------------         65     0.2%
 sigmoid   #####          1
```

Fig. 1. Visualization of the Multilayer Perceptron Architecture used in the Experiments.

With:

- k is the number of features for a sample.
- f_i is the value of the i-th feature.

IV. Cost-Sensitive Approaches in Deep Learning Algorithms for Imbalanced Datasets

A. Cost-Sensitive Methods

The goal of cost-sensitive learning for imbalanced classification tasks is to assign different costs to misclassification errors and compute those costs by specialized methods. A confusion matrix is a powerful tool for summarizing the predictions for the individuals and shows how well a method performs on a prediction. It allows the visualization of the performance of a learning algorithm. There are several common cost-sensitive methods including Cost-Sensitive Resampling, Cost-Sensitive algorithms, or Cost-Sensitive Ensembles. In this study, we investigate the performance of Cost-Sensitive Algorithms on an imbalanced metagenomic dataset.

The training section of learning algorithms uses the back-propagation to compute the error on the training set and update the weights based on those errors. However, the samples of each class are trained the same as each other, in the case of the imbalanced dataset, the model focus on the majority class more than the minority class. During back-propagation, the weight of misclassification errors can be updated in proportion to the

```
OPERATION           DATA DIMENSIONS   WEIGHTS(N)   WEIGHTS(%)

   Input   #####    443    1
  Conv1D    \|/  -------------------        256     0.9%
    relu   #####    441   64
 Flatten   ||||| -------------------          0     0.0%
           #####       28224
   Dense   XXXXX -------------------      28225    99.1%
 sigmoid   #####          1
```

Fig. 2. Visualization of the Convolutional Neural Network Architecture used in the Experiments.

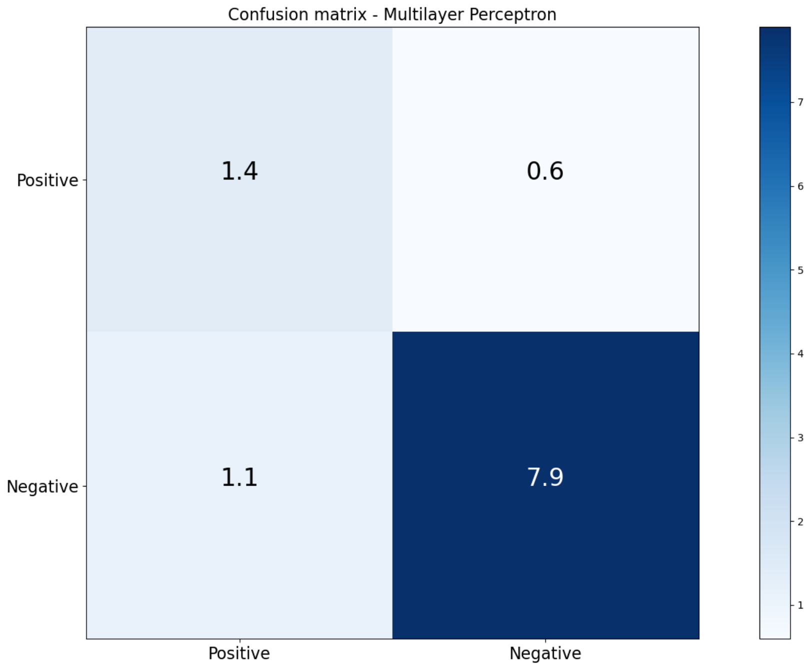

Fig. 3. The Average Confusion Matrix Result Running by Multilayer Perceptron with Cost-Sensitive Method.

importance of the class and have an influence on the model to pay more attention to samples of the minority class.

In our experimental results, computing the class weight from class distribution present in the training dataset can improve the performance effectively. The class weight can be computed by the Equation 2 inspired by the study [16].

$$w_c = \frac{n}{t * s_c} \tag{2}$$

Where w_c denotes the weight of class c, n represents for the number of samples in training set, t is number of class and s_c stands for the number of samples in class c.

B. Learning Models

To investigate the performance of training with Cost-Sensitive method and training without Cost-Sensitive methods, we used different architectures as mentioned above.

The Multilayer Perceptron (MLP) is a class of Artificial Neural Network (ANN), a MLP contains at least tree node layers. The input layer aims to receive the data while the hidden layers are the primary computational engines. The output layer produces the prediction result. The architecture of details of MLP used in the experiments is presented in Fig. 1.

Finally, the Convolutional Neural Networks (CNN) contains a $1D$ Convolutional layer, followed by a Fully Connected layer. The model learns an internal representation of a two-dimensional input, in a process referred to as feature learning. We visualized the CNN architecture in Fig. 2.

All three learning models are implemented with Adam optimizer [19], the default learning rate is 0.001. The Early Stopping method is also applied to avoid overfitting issues with a patience epoch of 5.

C. Metrics for Comparison

To evaluate the classification performance, we used three metrics namely Accuracy (ACC) and Area Under the Receiver Operating Characteristic Curve (ROC-AUC), and Matthews correlation coefficient (MCC). We investigated the accuracy and AUC of training with cost-sensitive and training with non-cost-sensitive. The accuracy and MCC are computed by the Equation 3 and Equation 4 respectively.

$$ACC = \frac{TP + TN}{TP + TN + FP + FN} \tag{3}$$

$$MCC = \frac{TP \times TN - FP \times FN}{\sqrt{(TP + FP)(TP + FN)(TN + FP)(TN + FN)}} \tag{4}$$

Where

- TP denotes True Positive.
- TN denotes True False.
- FP denotes False Positive.
- FN denotes False False.

Furthermore, the MCC is, in essence, a correlation coefficient of binary classifications. The MCC value has a range of -1 to $+1$. A coefficient of $+1$ represents a completely correct binary classifier, 0 stands for random prediction, whereas -1

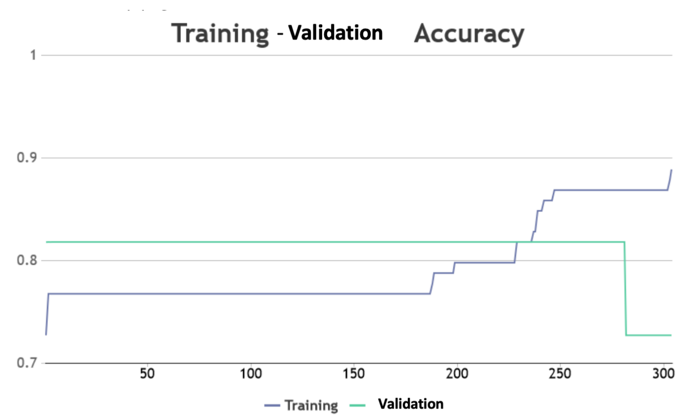

Fig. 4. Visualization of Training and Validation Accuracy of Multilayer Perceptron. X-axis Shows the Number of Epochs used in Training Phase while Y-axis Reveals Accuracy.

Fig. 6. Visualization of Training and Validation Loss of Multilayer Perceptron. X-axis Shows the Number of Epochs used in Training Phase while Y-axis Reveals Loss.

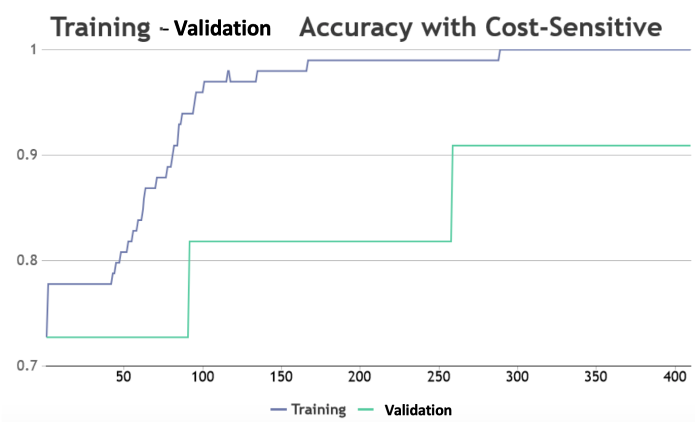

Fig. 5. An Illustration of Training and Validation Performance in Accuracy with Multilayer Perceptron Model using Cost-Sensitive Method. X-axis Shows the Number of Epochs used in Training Phase while Y-axis Reveals Accuracy.

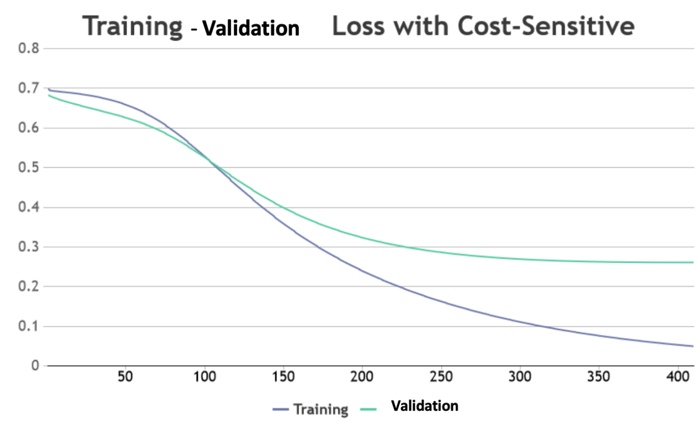

Fig. 7. Visualization of Training and Validation Loss of Multilayer Perceptron with Cost-Sensitive Method. X-axis Shows the Number of Epochs used in Training Phase while Y-axis Reveals Loss.

indicates total disagreement between prediction and observation.

Another metric is Loss which is also considered. The loss function implemented in networks in the study is Binary Cross-Entropy (Equation 5) [20]. The binary entropy function, denoted $H_p(q)$:

$$H_p(q) = -\frac{1}{N}\sum Ni = 1y_i.log_2(p(y_i))+(1-y_i).log_2(1-p(y_i)) \tag{5}$$

where y is the ground truth and p(y) is the predicted probability of the predicted sample.

V. Experimental Results

We trained all considered deep learning architectures with 10-folds stratified-cross validation. The performance of each model is measured by Accuracy, Area Under Curve (AUC), Matthews correlation coefficient (MCC), and Loss presented as follows.

A. *Performance of Multilayer Perceptron*

After 10-folds, the MLP obtained 0.77 of average overall accuracy, 0.643 of AUC, and 0.052 of MCC. The results are unsatisfied with the classification task due to the imbalanced dataset. We conducted training the model again with a cost-sensitive method and gained better results. More specifically, the accuracy increased to 0.845, 0.865 for AUC, and 0.552 for MCC. The exceptional increase of MCC stated the model was much better than before. Fig. 3 visualizes the confusion matrix of this learning model with cost-sensitive method. The average True Positive obtained 1.4, False Positive of 0.6, False Negative, and True Negative gained 1.1 and 7.9 respectively.

The training and validation accuracy of the compared methods are visualized in Fig. 4 and Fig. 5. Fig. 4 represents for the performance of non cost-sensitive. Otherwise, Fig. 5 visualizes the results of the cost-sensitive method, the training and validation accuracy got better epoch by epoch with the cost-sensitive method. Also with the loss, Fig. 6 and Fig. 7 present the training and validation loss of the learning model. As observed, the validation loss in Fig. 7 is better in comparison with the other in Fig. 6.

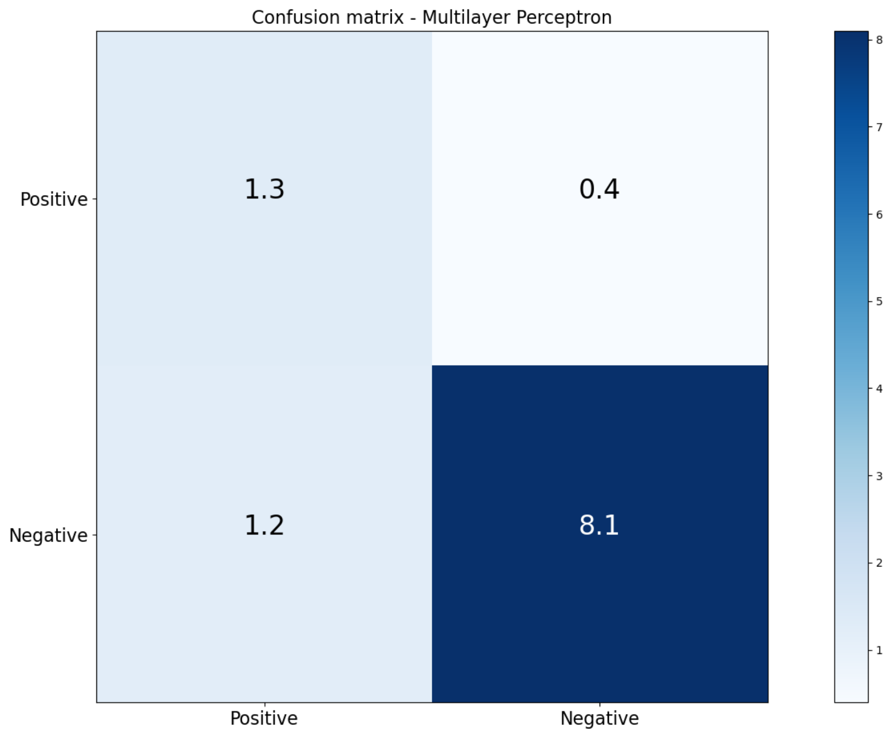

Fig. 8. The Average Confusion Matrix Result Running by on Convolutional Neural Network with Cost-Sensitive Method.

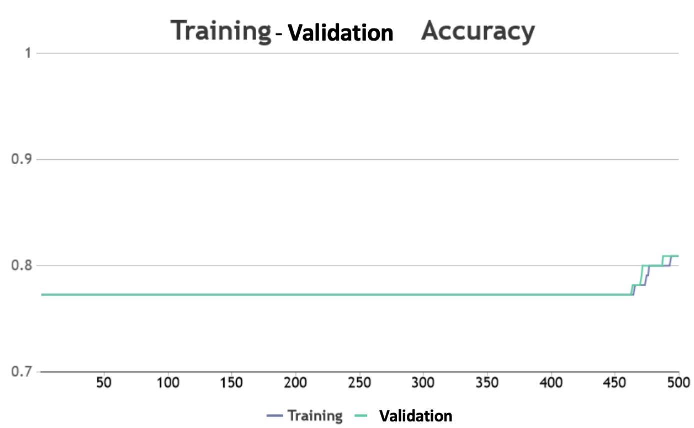

Fig. 9. Visualization of Training and Validation Accuracy of Convolutional Neural Network. X-axis Shows the Number of Epochs used in Training Phase while Y-axis Reveals Accuracy.

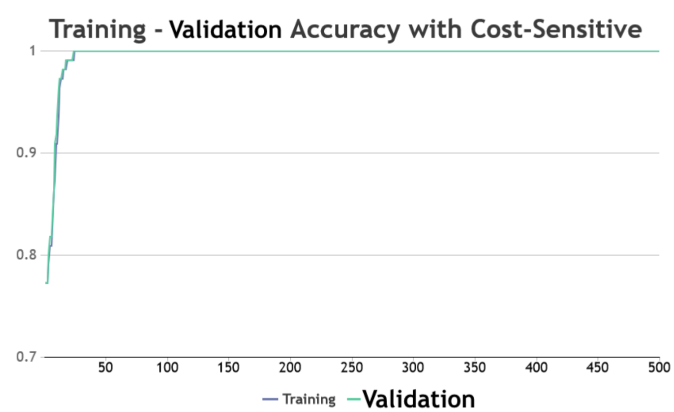

Fig. 10. Results of Training and Validation Accuracy with Convolutional Neural Network Combining Cost-Sensitive Method. X-axis Shows the Number of Epochs used in Training Phase while Y-axis Reveals Accuracy.

B. *Performance of Convolutional Neural Network*

We also investigated the performance of the Convolutional Neural Network on 10-folds cross-validation. In comparison with Multilayer Perceptron, the performance of the Convolutional Neural Network is very close. The average accuracy reached 0.773, AUC of 0.629, and MMC of 0. The boosted performance with the cost-sensitive method is slightly better, the accuracy increased to 0.855 but the AUC reached 0.871 and the MCC obtained 0.513. By applying the boosting performance method, the AUC of Convolutional Neural Network is better than Multilayer Perceptron whereas the accuracy and MCC are similar.

The confusion matrix of Convolutional Neural Network is visualized in Fig. 8. In comparison with the prior learning model, the values of True Positive, False Positive, False Negative, and True Negative are relatively similar. We also presented the training and accuracy/loss validation of Convolutional Neural Network in Fig. 9, Fig. 10, and Fig. 11, Fig. 12 respectively.

In the comparison of validation accuracy in Fig. 9 and Fig. 10, the validation accuracy of non-cost-sensitive method

Fig. 11. Visualization of Training and Validation Loss of Convolutional Neural Network. X-axis Shows the Number of Epochs used in Training Phase while Y-axis Reveals Loss.

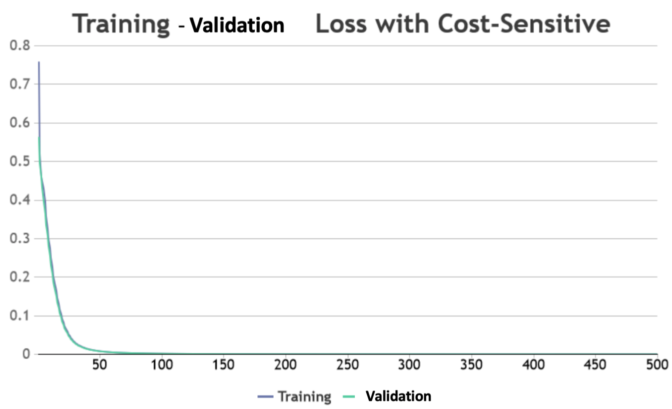

Fig. 12. Visualization of Training and Validation Loss of Convolutional Neural Network with Cost-Sensitive Method. X-axis Shows the Number of Epochs used in Training Phase while Y-axis Reveals Loss.

kept stable at 0.77 in almost training section and peaked at last epochs whereas the accuracy of model applying cost-sensitive reached the optimal performance around 50 epochs. Similar to Loss validation, the loss of non-cost-sensitive method stopped at 0.4 whereas the other is almost equal to 0.

C. Comparison of Multilayer Perceptron and Convolutional Neural Network

We summarized the performance of Multilayer Perceptron and Convolutional Neural Network in Table II. In general, the performance of the two learning models is similar. With the Cost-Sensitive method, the overall accuracy improved slightly but AUC and MCC were significant. The cost-sensitive method affected effectively to the classification performance.

VI. Conclusion

We introduced a method based on a Cost-sensitive approach to improving the performance of imbalanced datasets. The proposed method is efficient on not only Multi-Layer Perceptron but also Convolutional Neural Network.

TABLE II. The Comparison of Multilayer Perceptron (MLP) and Convolutional Neural Network (CNN).

Model	**Accuracy**	**AUC**	**MCC**
MLP	0.770	0.643	0.052
MLP with Cost-Sensitive	0.845	0.865	0.552
CNN	0.773	0.629	0.000
CNN with Cost-Sensitive	0.855	0.871	0.513

The performance is assessed by various metrics including Accuracy, AUC, MCC which reveal significant improvements with the cost-sensitive method. Besides, the proposed method enables the learning model to learn faster as well as speed up the convergence of models.

Further research can investigate more data and test on sophisticated machine learning algorithms.

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Design of Efficient Power Supply for the Proper Operation of Bio-Mimetic Soft Lens

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***Abstract*—Soft Robotics is one of the emerging and top-notched researched fields in Robotics which collaborate and Interact with Human Machine Interface (HMI). Several power electronics and electrical devices are used for the proper operation of these robots, among them high voltage power supply plays a vital role. Several approaches are used for the design of the high voltage power supply but still there is a deficiency in the design of the power supply which fulfill our desires level (highly efficient and less complex). This paper presents the efficient power supply for the control of bio-mimetic lens. The proposed power supply is designed by the use of boost converter, single phase inverter and the cock-croft Walton Voltage Multiplier. The work employs the use of power electronics for the achievement of the efficient high voltage power supply and boost the level of voltage up to 5 kV. Numerical simulations are performed for the comprehensive testing of the proposed model. Simulink is used for designing of the high voltage supply for simulation work. More-over the results are verified with the designing of laboratory setup. The experimental results are close to the simulation results with an error less than 3%. This proof the validity of proposed high voltage power supply.**

Keywords*—Cock croft walton multiplier; EOG; elastomers; bio mimetic lens; template

I. Introduction

High voltage plays an important role in the field of energy optimization, power electronics and plays a promising role in field of robotics. Robots have penetrated every corner of our daily life and legitimizing every aspect of it. The field of robotics have reinforced our will to achieve targets which were previously hard to achieve. Several kinds of robots are present like work assisting robots, Social robots, floor cleaning robot and window cleaning robot [1]. A new generation of robots is taking place over rigid robots termed as Soft Robots. Soft robots have been materialized by a hefty margin in last years. These robots encouraged by the essence of human bones and tissues are exceptionally manipulative and offer high rate of mobility as compared to anticipated hard robots which are made up of rigid materials [2],[3].

The kind of soft robot unto which this research is based upon is soft lens or robotic lens. Soft lens provides human to machine interface and falls under the category of tunable optical component [4]. The actuation in the soft lens is manipulated by the use of EOG signals. Since EOG signals are in order of milli-volts. The dielectric elastomers (DE-As) are used in the soft robotics for the conversion of the electrical energy into mechanical energy by producing the large strains [5]. High voltage is required for the proper operation of the DE-As [23]. The robots using elastomers require the use of the DC to DC converter for of the high potential requirements. The direction of the research is on the design of the efficient power supply for the proper operation of soft robots [6].

In the previous studies the high voltage power supply has been designed by using different power electronic techniques[24],[25]. The design of efficient high voltage power supply requires enough time and money. In one research the use of transformer is made for the achievement of the high voltage [7]. The transformer used in this case is step up transformer. The use of transformers is not suitable for the field of robotics and in case of advanced research in electrical and electronics engineering. Moreover, the losses in transformer increases its limitations for the use in power supply. Saturation of the transformer leads to the distortions in the secondary side during short circuit. Moreover with this saturation the failure of the protection system occur and this leads to the system failure in severe cases. One of the major limitation of the use of transformer is its poor response during high frequency cases [8],[9],[10]. As the use of transformer makes circuit bulky, increase distortion in input current and increases power dissipation, therefore its use is limited to conventional linear power supply. In order to mitigate the limitations in the conventional linear power supply the use of the of the high frequency switching technique has been used by one group. They proposed by minimized circuit containing the boost converters. The boost circuit step up the level of the DC voltage with the use of the inductor, capacitor and the transistor [11]. In another the research the use of the two boost PFC (power factor corrector) converters are used for the achievement of the high voltage with higher efficiency. The use of the adaptive technique is made for maintaining the output voltage at desired level [12]. The limitation with this approach is the switching noise and the losses due to use of transistor at high voltage level. In order to overcome the limitations with boost converters, cock croft multiplier technique is proposed by one group. This circuit used the number of the capacitors for the achievement of high voltage. Voltage multiplier circuits are used primarily to develop high voltages where low current is required. The Voltage multiplier circuit which has the ratio of output voltage to input voltage depending on number of stages [13],[14].

This paper presents a precious approach for designing of efficient power supply to control the operations of bio mimetic soft lens. The proposed power supply consist of three main parts for achieving the high voltage and goal behind this division is to mitigate the limitations of previous approaches. Among the three parts (boost circuit, inverter circuit and the cock-croft) cock-croft Walton voltage multiplier circuit plays a vital role. This method works by taking the small input voltage and boost them to higher level with higher efficiency in order to control the lens. The model has been designed on MATLAB software and the verification of the methodology has been carried out in the laboratory environment.

The proposed work is categorized into following sections. In Section II mathematical modeling of the proposed system has been carried out. Section III shows the methodology of the presented power supply and the numerical simulations are presented in Section IV. Further the laboratory setup and the conclusion are explained in Sections V and VI.

A. Mathematical Modeling

The proposed method is based on the mathematical modeling of the booster circuit, inverter circuit and the cock-croft walton multiplier.

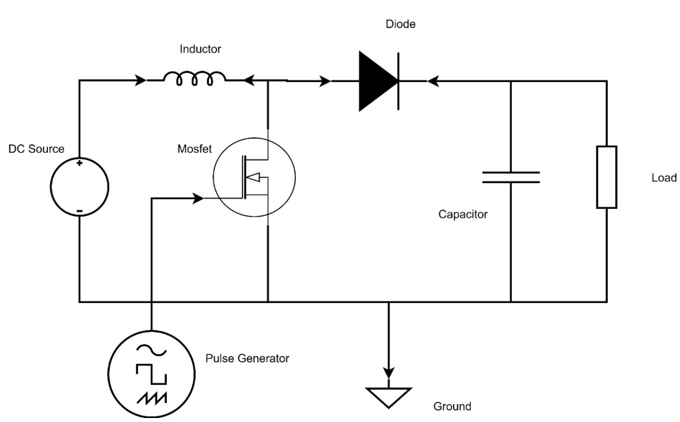

Fig. 1. Boost Converter System

1) Boost converter: In boost converter usually the output voltage are greater than the applied voltage. Turning on the controlled switch, the current flow through the inductor and it stores the energy as shown in Fig. 1. The storage of current charge results in the magnetization of inductor and when the switch is turned off, the current flow across the inductor shifts towards zero and results in demagnetization of inductor. The inductor now acts as voltage source to provide the sufficient voltage to the circuit by the reverse in its polarity. The voltage across the inductor and the applied voltage together charge the output capacitor placed across the load with a voltage higher than the input voltage and results in the boost of the voltage. Due to operation in CCM (continuous conduction mode) the current never drops to zero [15].

The boost converter follows two state operation, open or closed. When switch is closed, the current flow across the inductor and rise the clock pulse and in open state the reverse operation exist. When the controlled switch is in on state [16]:

$$\frac{d_i}{d_t} = \left(\frac{V_{i_n}}{L} - \frac{r_i}{L}\right) * I \tag{1}$$

$$\frac{d_{v_c}}{d_t} = \frac{V_c}{C} * (R + r_c) \tag{2}$$

During the off state the mathematical equations becomes

$$\frac{d_i}{d_t} = \left(\frac{V_{i_n}}{\frac{L-I}{L}}\right) * \left(\frac{r_l + R_{r_c}}{R + r_c}\right) - \left(v_c * \frac{R}{L} * (R + r_c)\right) \tag{3}$$

$$\frac{d_{v_c}}{d_t} = \frac{1}{C}(R + r_c) * (R_i - r_c) \tag{4}$$

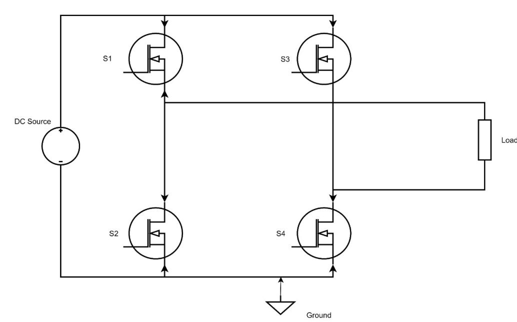

Fig. 2. Inverter Model

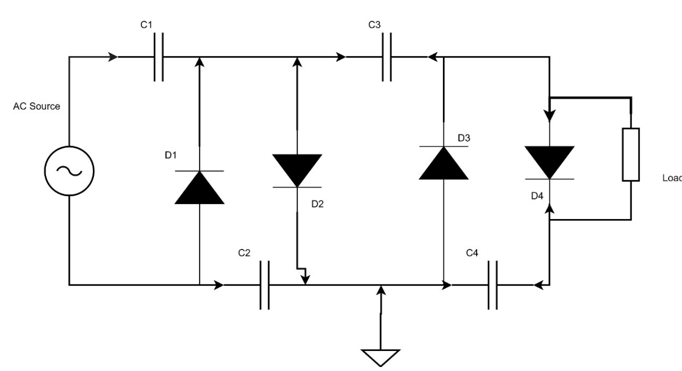

Fig. 3. Cock-croft Walton Multiplier

2) Inverter: Inverter is the device used for the conversion of the DC voltage into AC, its circuit diagram is shown if Fig. 2. The switching frequency of the inverter can be written as [17].

$$Frequency = f_o = \frac{1}{2} * \pi * R * C \tag{5}$$

3) Cock croft Walton Voltage Multiplier: The peak surge current rating of the mostly rectifier diode has to be assigned with respect to the input voltage rating, shown in Fig. 3. In this work the peak surge current is one of the main factor to in dose the persistence would be the selection of diode. It might be the rectifier diode combination are more important is to control the forward surge current corresponding to the large capacitive loading effect. The surge current might have not damage the appearance of capacitor at the load. The load current are the limiting factor to maintain the overall consistency of diode working [18]. For the n-stage of the rectifier diode circuit is associated to develop the load due to the large rating of capacitor and the capacitive loading effect are the main reason is to establish them selves the diode set up in the cascade system of component. Here number of stages has to be increase the forward surge current are developed at the load greater the number of capacitor larger will be the total capacitance which should be obtained during the experimental setup and can be expressed as [19],[20].

$$C' = nC_1 \tag{6}$$

$$n = \frac{N_2}{N_1} \tag{7}$$

$$C = \frac{V_{p_{ea_k}}}{R_s} = \sqrt{2}\frac{V_{R_{M_S}}}{R_s} \tag{8}$$

Forward voltage drop is given as

$$V_{f_d} = \frac{I_{l_{oa_d}}}{6fC}(n^3 + 2n) \tag{9}$$

Whenever high voltage generating circuit is loaded, a fluctuation in the output DC voltage δV appears, which depends on the supply and frequency is known as ripple.

$$\delta V = I_f(1C_n + 2C_{n_{-1}} + \ldots.. + nC_1) \tag{10}$$

From above equation it is shows, in multiplier circuit a low voltage rating capacitors are responsible for most ripple. Therefore, capacitors of different values are calculate in practical circuits and the ripple for circuit is given as

$$\delta V = IfCn(n+1)^2 \tag{11}$$

This quantity is to be evaluated is the voltage drop Vd across each stage and also calculated the overall voltage in regular manner. That make feel a difference of practical approach over the theoretical way no load voltage 2nVmax and the on load voltage

$$V_d = \frac{I}{fC}\left(\frac{2}{3}n^3 + \frac{1}{2}n^2 - \frac{1}{6}n\right) \tag{12}$$

$$Voltageregulation = \frac{V}{2nEm} \tag{13}$$

II. Method for the Design of Efficient High Voltage Power Supply

The proposed method is based on the design of the efficient power supply for the generation of high voltage. The power supply working methodology is discussed in the three parts. The method starts with the working of boost converter, working of inverter comes after the boost converter. The method presented in this work ends with the use of the cock-croft walton multiplier. The boost converter is used for the increase in the level of the voltage up to desired state. In this work the major focus is on the states occurred during switching mode. One is the continuous conduction mode (CCM) and the other is the Discontinuous conduction mode and in this case conditions are made to operate our sytem in (CCM) and to avoid the operation in (DCM). The feedback mechanism has been used to maintain the output DC Voltage at specific frequency level (2.4 kHz) obtained by considering the design parameters of converter. Boost converter has two states with respect to the time and flow of current across the conductor changes with the change in the polarity. Charging and discharging of the inductor increase the voltage level and it is made possible by controlling the switch (MOSFET). The control of switching frequency is made possible through the driver circuits operates on the pulses (PWM) from Arduino. The booster in this work takes 5 V at the input terminal boost them to 12 V and control them at desired level (12 V). An opto-coupler (4N28) has been used to control the feedback loop. The Single phase pure sine wave DC-AC inverter is the second part of an efficient power supply. It consists of H-bridge and a step-up transformer. H-bridge is the main operating part of the inverter which converts the DC input into AC output. The conversion takes place through proper switching with the use of MOSFET. The H-Bridge contains a series of four controllable switches in which there are two sets of two switches. One set of switches when closed allows electricity to flow in one direction and the other set allows electricity to flow in the opposite direction. The LC Filter is used to remove the extra spikes and results in pure sinusoidal AC output. Two types of losses occurs in the inverter used in this work, one is electromagnetic interference which exists due to the fast change in the polarity. This loss results in the damage of inverter. The second loss occur when the spike of voltage is more than the system can tolerate. Significant or sometimes catastrophic damage to the device itself caused by this loss. In case of protection from these losses snubbers are used to limitize the level of losses and rescue the device from the internal damage. Moreover it reduces the voltage transients in the electric system. RC snubbers are typically used before the H- Bridge to control the sudden voltage spikes occur and diode snubbers are used to control the output current flow to protect electronics components placed inside the inverter. The inverter converts the 12 V DC to 12 V AC and with the use of

TABLE I. Boost Converter Model Parameters

Equipment	Values
Capacitor	33 uF
Inductor	9 mH
MOSFET	2.4KHz (switching)
Load Resistance	60 ohm

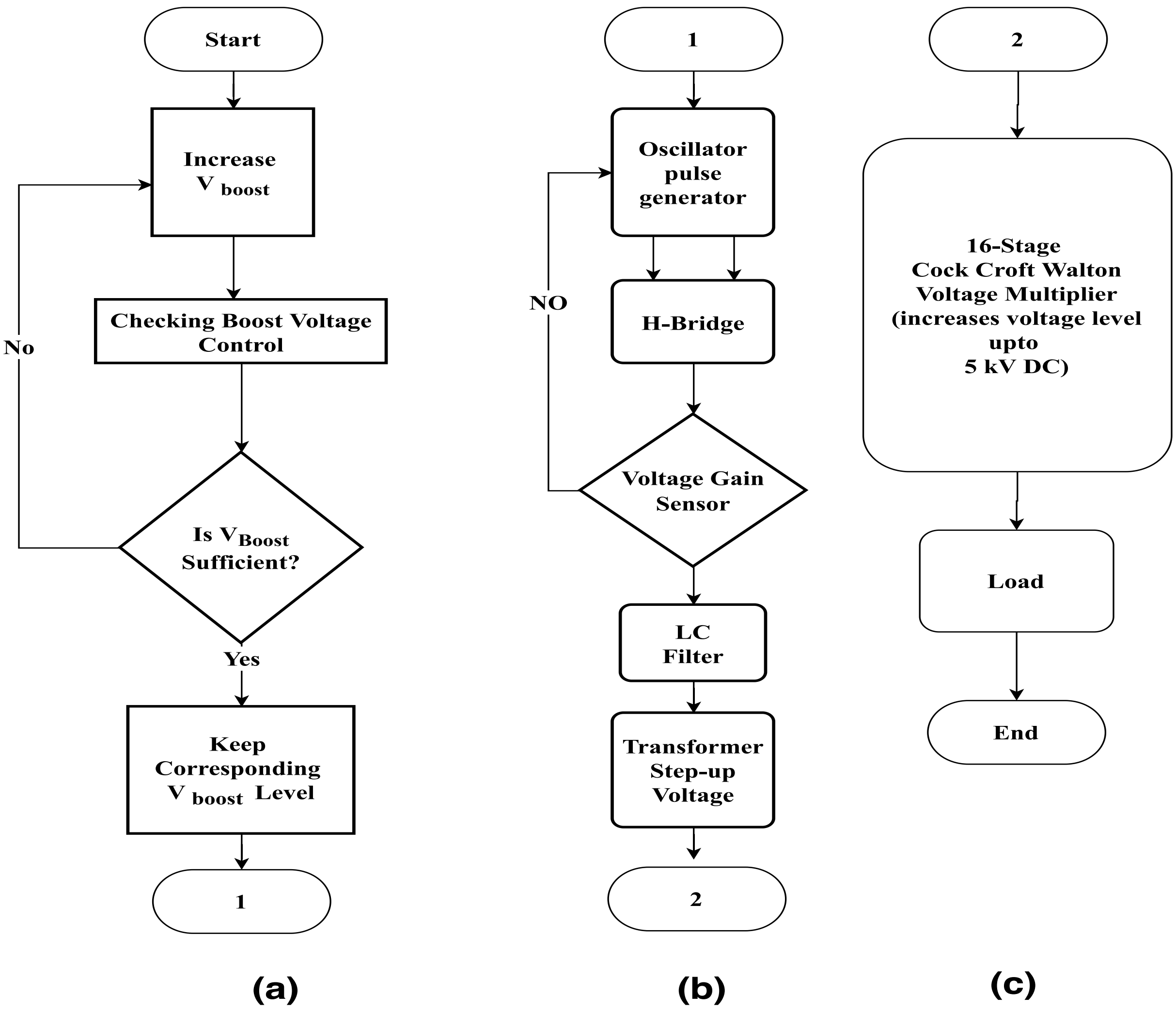

Fig. 4. Proposed Methodology (a) Boost Converter (b) Inverter (c) Cock croft Multiplier

transformer the 12 V AC is converted into 320 V AC. These voltages are moved towards the last stage of power supply. Cock-croft walton voltage multiplier is the third stage and main part of our high voltage power supply. It consists of a cascade or multiplier circuit and the devices are arranged in the ladder form. The increase in voltage has been made stage by stage with the use of the rectifier circuit. In rectifier circuit the diodes and capacitors are placed parallel to each other. The main objective behind the use of multiplier circuit is to increase the level of input voltage by adding the stages of rectifier circuit. As the capacitor store the charge to some extent and increase the voltages stage by stage to several kV, with the constant voltage drop across each stage. The main focus is to maintain the load impedance with a constant voltage drop at each stage. The output current rating is in milli-ampere to avoid any damage to the electronics component or complete device. The voltage multiplier is easy to design but the selection of components is very difficult. To understand that the selection of capacitors and diodes are based on different parameters. The input frequency is the main reason for the selection of these electronics components. With the use of the cock croft walton voltage multiplier, we are able to obtain the desired level of voltage (5 kV) by increasing the level from 320 V AC to 5 KV DC. The whole methodology is shown in Fig. 4.

TABLE II. INVERTER MODEL PARAMETERS

Equipment	Values
Snubber Resistance (Rs)	660 ohm
Snubber Capacitance (Cs)	1 nF
MOSFET	50 Hz (switching)
Load Resistance	150 ohm
Low Pass filter	L= 0.5 H, C= 33 uF

III. NUMERICAL SIMULATIONS

This paper presents the efficient high voltage power supply for the tun-able soft lens. The High voltage power supply consist of various power electronics applications that utilize to build a high voltage power supply. Simulink is used for the modeling of power supply and the model starts with the

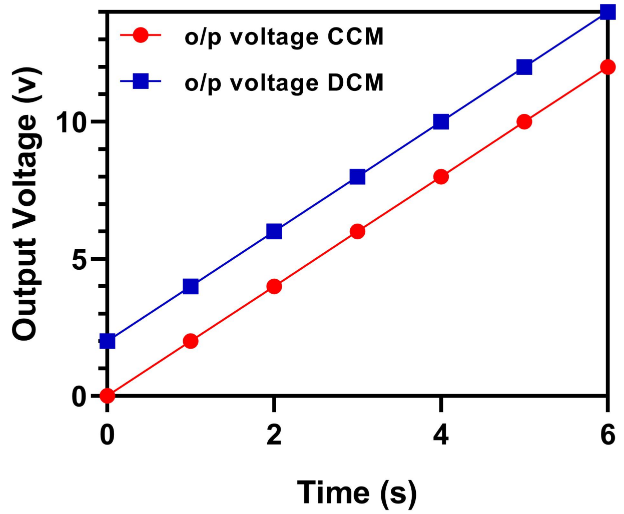

Fig. 5. Boost Converter Operation in CCM and DCM

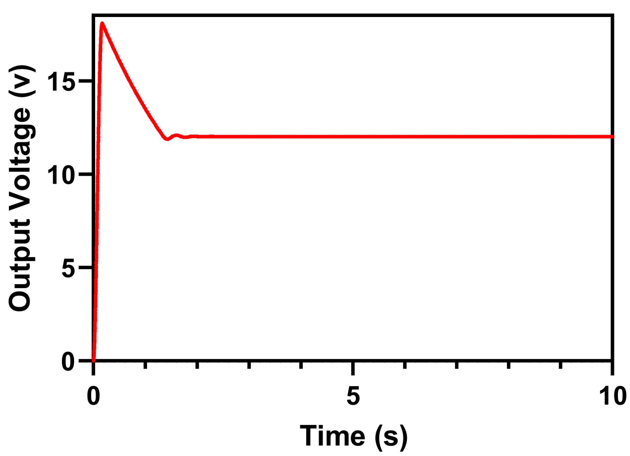

Fig. 6. Boost Converter Operation

designing of boost converter. The parameters used for the designing of boost converter are shown in Table I.

Fig. 5 show boost converter operation in continuous conduction mode (CCM) and discontinuous conduction mode (DCM). The output voltage rises constantly for time and the load current shall remain the same during CCM. In DCM the output voltage changes its position and variate from different point to point connection. In this method the boost converter operates in CCM and plays an important role for step up the low input DC voltage to desired continuous DC output Voltage. In real time scenario the inductor current never falls to zero and stay modulated in the positive side. Boost converter can step up the 5v input to 12v output with operation in CCM as shown in Fig. 6. A feedback mechanism maintain the output voltage in the CCM and perform the stepping action. The output load are the main part of boost converter as it decide the switching modes whether it can be in CCM or DCM. The load impedance could match according to the capacitor placed parallel to the output load. Moreover the output voltage ripple is 5% and the inductor current ripple is 20%. The second part of the high voltage power supply is the pure sine wave single phase inverter. In Simulink, this block of single-phase inverter produced AC output from the Continuous DC input. The inverter can convert the DC input of 12v into 12v AC by proper switching of high voltage MOSFET using the H-bridge arrangement. The parameters of inverter are shown in Table II.

Inverter consist of Two pairs of two fast switching MOSFET which can convert DC into Square wave output as shown in Fig. 8. Te use of low pass filter has been made for obtaining the sinusoidal wave from the square wave as shown in Fig. 9. The transformer is used with the inverter for increasing the voltage level to 320 V. The parameters of transformers are shown in Table III. The output obtained after amplification from transformer is shown in Fig. 10. Cock-croft Walton voltage multiplier circuit consist of ladder arrangement of the capacitor and diodes. Capacitors and diodes are chosen based on the input voltage and the suitable parameters of previous blocks of the boost converter and the single-phase inverter with step-up Transformer. For the selection of the capacitor and diode depends upon the frequency of the input voltage. The range of capacitor is 0.2mF to 0.4mF the output voltage ripple would be the 5% of the output voltage. The parameters of Cock-croft Walton is shown in Table IV. The CWM increases the voltage level to near about 5 kV, as per requirement for the operation of control of lens. The step wise increase in the level of the voltage with each stage is shown in Fig. 11 and whole circuitry designed in Simulink is shown in Fig. 7.

TABLE III. STEP UP TRANSFORMER PARAMETERS

Equipment	Values
Power	250 kV
Frequency	50 Hz
Input	12 V
Output	320 V

TABLE IV. CWM PARAMETERS

Equipment	Values
Capacitor	470 uF
Load resistor	1 Mega ohm
Input	320 V
Output	5000 V
Output voltage ripple	5%

IV. EXPERIMENTAL SETUP

Experimental set up has divided into three main stages, boost converter inverter and cock-croft Walton voltage multiplier. Boost converter is designed with the used of the bread board and the wires by connecting the electronics devices and

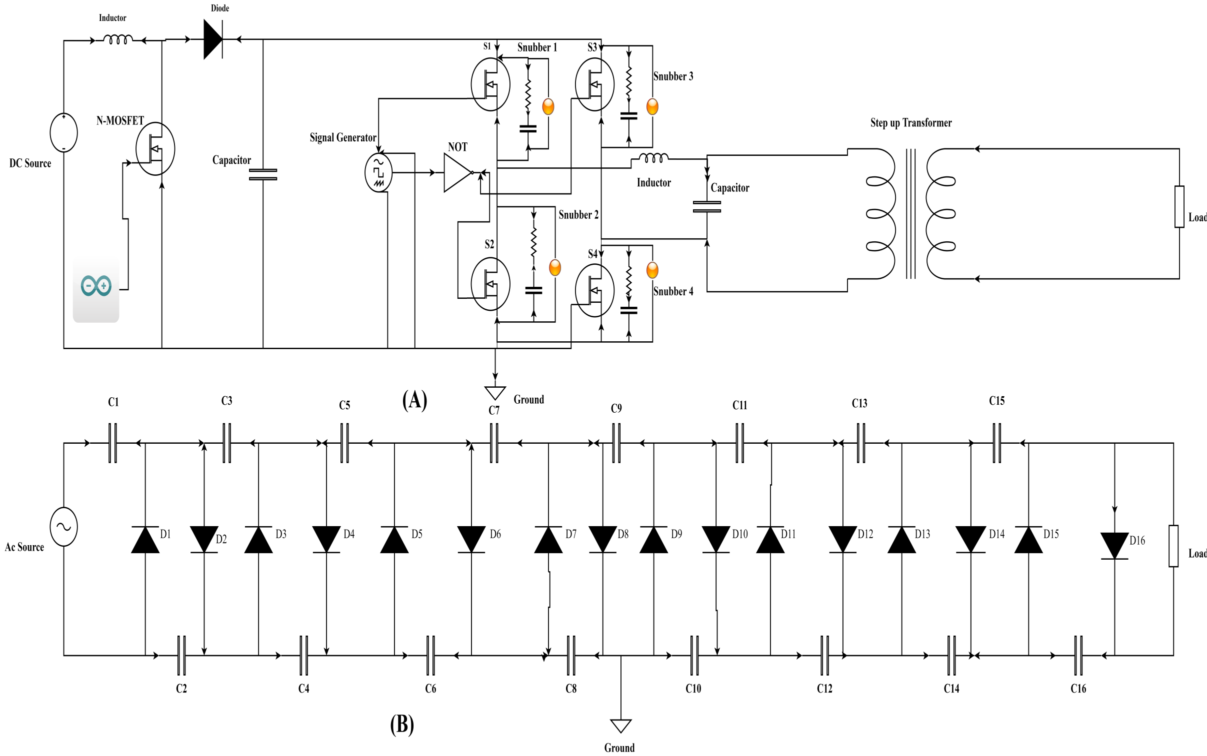

Fig. 7. Complete Circuitry of Power Supply (A) Boost Converter and Inverter (B) Cock croft Multiplier

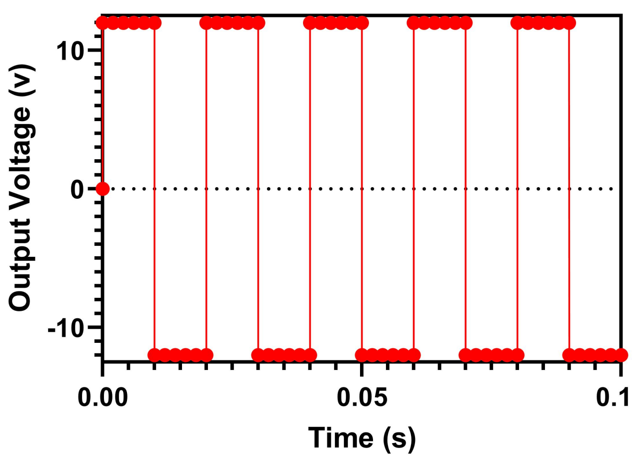

Fig. 8. Square Wave

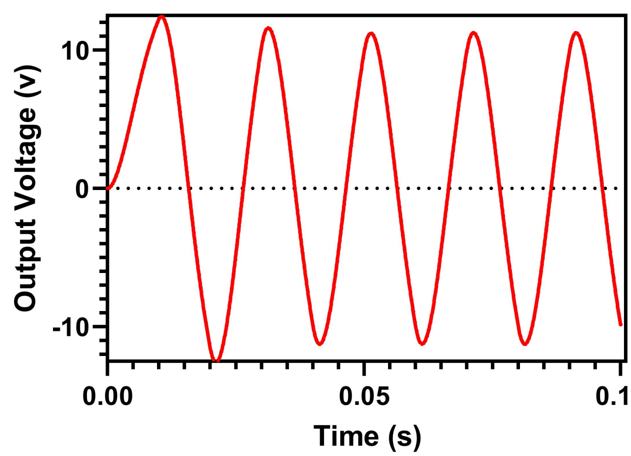

Fig. 9. Pure Sine Wave Results

the controller with low voltage power supply. Pulse Width Modulation(PWM) is used with the help of controller to run the gate of N-channel power MOSFET (IRF-540), low voltage inductor of 10 mH, power diode (2N2222), Ceramic capacitor of 33uF with low ESR and an opto coupler for reference voltage in close loop is used for increasing the voltage level from 5 A to 12 V DC. Moreover a digital multi-meter and oscilloscope for data acquisition. All these electronic component placed and connect on breadboard and observe the output result. The experimental setup for the design of boost converter is shown in Fig. 12.

Inverter is used for the conversion of DC to AC and transformer boosts the level of the voltage from the 12 V AC to the 320 V AC. Cock-Croft Walton Multiplier circuit works after the generation of 320 V AC and is a cascade system with ladder arrangement of capacitor and diode which can be placed on breadboard in parallel arrangement. A multiplier circuit consist of two types of capacitors through which increase in the voltage level stage by stage obtained with different intensity of spark at the output. The intensity of spark is

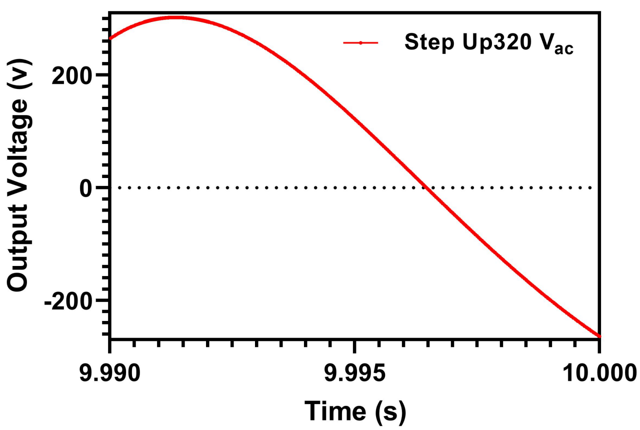

Fig. 10. Step up Transformer Result

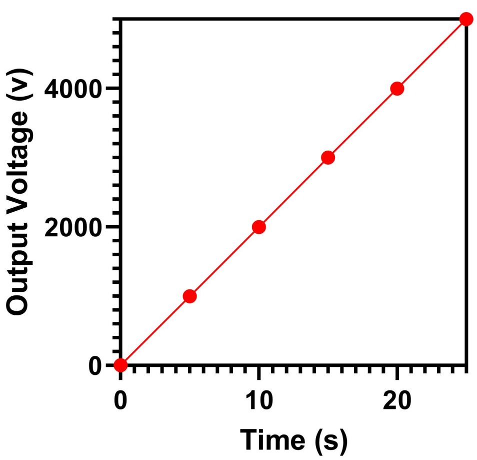

Fig. 11. CWM Results

directly proportional to the distance for which the spark has generated and the distance of spark would be the 10 mm of 5 kV high voltage. Two types of capacitor has been used in this experiment for increasing the level of voltage, one is polyester sheet capacitor (2.2 nF) and the other is ceramic capacitor (470 uF).

A. Experiment using Polyester Capacitor

Polyester sheet capacitor is a high voltage rating capacitor and it is used in high voltage power supply to store the charge stage by stage. Film (polyester) capacitor are used for the high frequency power application as they maintain the temperature to save the device. High voltage probe has been used for further modification and obtained the best results for the operation of soft lens as a capacitive loading effect. The experimental setup has been shown in Fig. 13 [21].

B. Experiment using Ceramic Capacitor

The ceramic capacitor have high voltage rating and it operates at low frequency of input line voltage. The ceramic capacitor charging and discharging rate are very slow and it takes a while to store the charge and boost up the input voltage stage by stage. Its Equivalent series resistance is very low and the voltage drop across each side is different with respect to the rate of charging and discharging. While air space would be the very good insulator which can either stop the spark. The voltage rating of ceramic capacitor depends upon the nature of load and the value of capacitor depends upon the input switching frequency of applied voltage. The voltage rating of capacitor is 470uF and 6000v threshold voltage [22]. High voltage diode which allow or block the voltage. It is very important to maintain the polarity of capacitor when source reverses its polarity. The forward voltage drop is 0.7v and the output voltage ripple is 5%. The experimental setup using ceramic capacitor is shown in Fig. 14. The spark of film capacitor is greater than the ceramic capacitor to achieve desired level of voltage. The use of CWM allow us to generate nearly about 5 kV and the results are closely related to the simulation work results.

V. Conclusion

This work employs design of an efficient power supply for the proper operation of bio mimetic soft lens. The proposed high voltage power supply plays a vital role inn the field of power electronics and soft robotics .Designing of Boost converter and Cock-Croft Walton Multiplier are the main parts of efficient power supply. Boost converter has been designed under the continuous conduction mode and step up voltage 5v to 12v with the promising output conditions. The linear behavior of boost converter is to maintain the DC level at the output. Cock-croft Walton Voltage multiplier circuit is used to attain a high output voltage with low output current. The Cock-croft Walton Voltage multiplier circuit plays an Important role in the emerging field of power electronics and it works by taking a very low AC input voltage boost up stage by stage to the higher level with greater efficiency. In order to control the basic operation of soft lens 5kV output DC voltage has been required which would be obtained by this multiplier circuit. This model has been designed in MATLAB (Simulink) for the simulation and numerical analysis and the practical verification of this model has been carried out in the laboratory environment. The result of numerical simulation and the laboratory model are closely related to each other with the error less than 3%.

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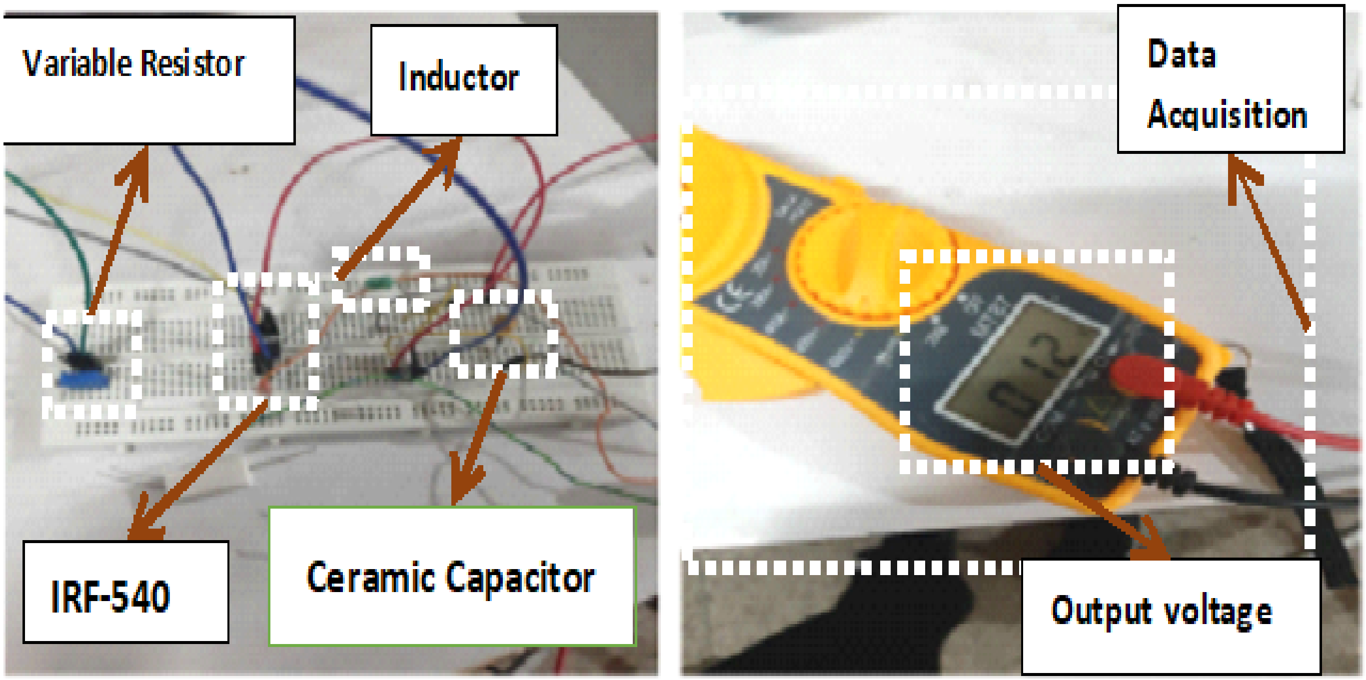

Fig. 12. Experimental Setup of Boost Converter

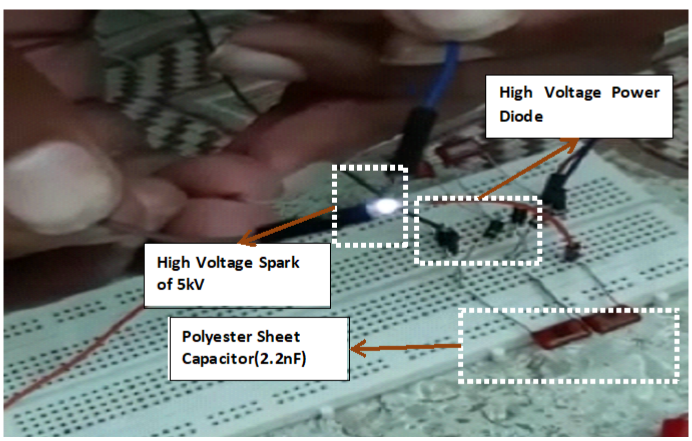

Fig. 13. CWM Design using Polyester Capacitor

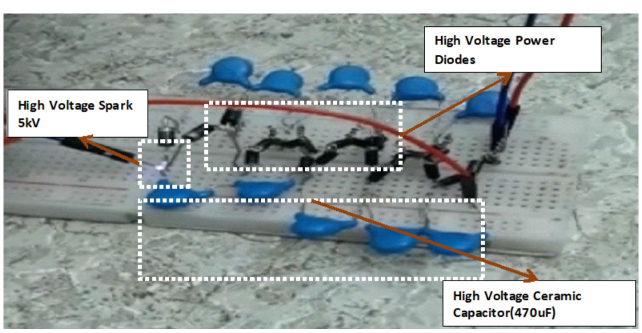

Fig. 14. CWM Design using Ceramic Capacitor

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Viral and Bacterial Pneumonia Diagnosis via Deep Learning Techniques and Model Explainability

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***Abstract*—Pneumonia is one of the most serious diseases for infants and young children, people older than age 65, and people with health problems or weakened immune systems. From numerous studies, scientists have found that a variety of organisms, including bacteria, viruses, and fungi, can be the cause of the disease. Coronavirus pandemic (COVID-2019) which comes from a type of pneumonia has been causing hundreds of thousands of deaths and is still progressing. Machine learning approaches are applied to develop models for medicine but they still work as a black-box are difficult to interpret output generated by machine learning models. In this study, we propose a method for image-based diagnosis for Pneumonia leveraging deep learning techniques and interpretability of explanation models such as Local Interpretable Model-agnostic Explanations and Saliency maps. We experiment on a variety of sizes and Convolutional neural network architecture to evaluate the efficiency of the proposed method on the set of Chest x-ray images. The work is expected to provide an approach to distinguish between healthy individuals and patients who are affected by Pneumonia as well as differentiate between viral Pneumonia and bacteria Pneumonia by providing signals supporting image-based disease diagnosis approaches.**

***Keywords*—Interpretability; pneumonia; x-rays images; bacterial and viral pneumonia; image-based disease diagnosis**

I. Introduction

According to the World Health Organization (WHO), pneumonia is one of the most infectious causes of death worldwide, it affects children and families everywhere and causes 50 thousand deaths each year. Recently, the Situation Report - 150 from WHO [1] about COVID-19 presented the number of infected active cases is up to $8,2$ million, the number of deaths is $445,535$. The patients can get pneumonia as a complication of viral infections such as COVID-19 or the common flu. Besides, the bacteria, fungi, and other microorganisms can also be the primary infectious agents of pneumonia, causing cough with phlegm or pus, fever, chills, and difficulty breathing. Pneumonia is the infection of one or both lungs and filled up with fluid and pus. Based on [2], up to 60% of the cases are related to respiratory virus infections. The study in [3] indicated the difference between viral and bacterial pneumonia in children is based on the serum C reactive protein (CRP) but the sensitivity is not enough for use in clinical practice.

In the field of medicine, diagnostic radiology is significant and used for disease assessment. To detect the pneumoconiosis early and accurately after the clinical analysis, performing a chest X-ray is important and necessary. It is critical to preventing complications including death. The expert radiologists assessed the X-ray images for the pneumonia fluid in the lungs during the diagnosis. Specifically, Fig. 1 contains images of viral (left image), bacterial (middle image) and normal chest (right image) pneumonia. Viral pneumonia presents the diffuse interstitial pattern in both lungs, whereas, bacterial pneumonia typically exhibits a focal lobar consolidation.

Furthermore, chest X-ray (CXR or chest radiography) can reveal the abnormalities areas and not only produce images of the chest but also the nearby structures. Nevertheless, the X-ray images consist of black and white colors, it is quite difficult for detecting the infected areas in the images. Additionally, the technical level of radiologists is also important to make the diagnosis correctly. A study in [4] conducted an education in-person training for improving chest radiograph interpretation accuracy among non-radiologists clinicians.

In recent years, the complexity of medical data makes it more difficult for analyzing and diagnosing the disease. In parallel, the improvements in Machine Learning and Deep Learning have a certain influence on image processing in general and medicine in particular. The diagnosis process performs with Machine Learning or Deep Learning can help physicians investigate the medical images conveniently and reduce the analysis time. Several studies have resolved the challenging tasks such as medical image classification [5], [6], skin cancer detection using images [7], or 3D image biomedical segmentation [8].

Moreover, Deep Learning-based technologies have successfully demonstrated in clinical practice including clinical decision support systems (CDSS), diagnosis prediction, and predicting the invasiveness of lung adenocarcinoma manifesting based on radionics and clinical features [9]. Though, there are still several challenges with Machine Learning. Selecting a dataset, creating a predictive model, and evaluating and refining the model, the most important thing is data [10]. The implementations of Machine Learning or Deep Learning in health care are influenced by the accuracy of medical data. Specifically, the annotation progress in the medical image is based on medical professional knowledge, medical industry standard, and medical system [6].

II. Related Work

The exceptional improvement of Deep Learning and large datasets have facilitated for the replacement of artificial intelligence for human gradually. As we mentioned above, several studies have outperformed the performance of medical experts.

A study from Stanford University Machine Learning Laboratory [11] proposed a Deep Learning structure, namely CheXNet which contains 121 convolutional layers for detecting pneumonia. They evaluated the model on a large dataset - ChestX-ray14 [12], including over 100,000 chest X-ray images with 14 diseases. The authors resized the original images to 224×224 and applying the random horizontal flipping before training. Their proposed method can detect all 14 diseases in ChestX-ray14. However, it also contains several limitations. The X-ray images are in the frontal view for training and testing, but a study in [13] indicated that up to 15% of accurate diagnoses need the lateral view. Furthermore, the patient records are not allowed to use, which has affected negatively by radiologist diagnostic performance [14].

The authors in [15] studied the powerful performance of Residual Neural Network (ResNet) [16] on several diseases using the ChestX-ray14 dataset for classification tasks. The high spatial resolution of X-ray images is investigated by the extended ResNet-50 and the non-image features including patent age, gender, and view position are transformed into a non-image feature vector and concatenated with the image feature vector. In general, the integration with the non-image feature reached the best overall performance, the detailed analysis of the non-image feature has been provided.

The following approach [17] takes advantage of the Laplacian of Gaussian (LoG) filtering to improve the performance of the Convolutional Neural Networks. The considered dataset contains 247 radiograms from the publicly available Japanese Society of Radiological Technology dataset (JSRT). The original images are downsized to 96×96 and applied the LoG filter before training or testing. The performance of the Deep Learning model is evaluated based on the detection of the nodule in X-ray images, the results reached better performance in comparison with AlextNet [18] and GoogleNet [19].

The authors in [20] proposed an approach that supports the disease diagnosis with trained models and Gradient Class Activation Map (Grad-CAM) method [21]. The results from Grad-CAM have been generated based on the features that the models pay the most attention to. But the performance of Grad-CAM depends on how good the models are. This study also investigated the performance on a specific size of the image, which is 64×64 with a shallow Convolutional Neural Networks.

In an attempt to describe the chest radiographs of patients with bacterial and viral pneumonia, the study in [22] let the radiologists reviewed the chest X-ray from pneumonia patients. The results stated that the comparison of bacterial and viral pneumonia is insignificant differences and chest radiographs are hard to recognize between bacterial and viral pneumonia.

In this study, we propose a CNN-based method to distinguish between bacterial and viral pneumonia, stratify healthy samples and patients. We also explain output from trained models with model-agnostic and saliency maps to extract signals in images for the diagnosis. Our contributions include:

- We introduce Convolutional Neural Networks to discriminate healthy individuals and patients who were affected by viral pneumonia or bacterial pneumonia. We also distinguish viral pneumonia and bacterial pneumonia from chest radiography. The performances on several categories are evaluated (For instance, normal-viral-bacterial, normal-viral, normal-bacterial, and viral-bacterial).
- Various sizes of images, in specific, 64×64, 96×96, and 256×256 are also carried out to compare the performance.
- We leverage the advantages of Local Interpretable Model-agnostic Explanations (LIME) [23] and Saliency maps [24] for visualizing the discriminate features in the X-ray images. The disease diagnosis process can be easier with the proposed method.
- Oversampling technique is also implemented in the case where we face imbalanced image datasets for prediction tasks. As a result, the performance in image classification is improved.

In the remainder of this study, we introduce the considered dataset and model structures in Section III. The works with LIME and Saliency maps are explained in Section IV. Our experimental results are presented in Accuracy, Area Under the Curve (AUC) of the Convolutional Neural Networks for several classification tasks in Section V. We conduct and summarize some remarks in Section VI.

III. Convolutional Neural Network for Pneumonia Images

A. Dataset

The publicly available dataset from Guangzhou Women and Children's Medical Center, Guangzhou [25] is considered to evaluate our method. The quality control and quality assurance have been done by two expert physicians. In specific, the low quality or hard-to-read images were removed, then, the images were classified by the experts. The dataset includes 5856 X-ray images in which, 1583 images are labelled $Normal$ and 4273 for $Pneumonia$. To categorize the viral and bacterial pneumonia, we split the $Pneumonia$ class into two sub-classes, namely $Viral$ and $Bacterial$ with 1493 and 2780 samples respectively, more details are in Table I. Fig. 1 visualizes the samples of 3 classes as we mentioned above. For the classification tasks, we split the dataset into a training set and validation set randomly with a ratio of $9:1$.

We have three binary classification tasks and one multi-class (three classes) classification task. The X-ray images are

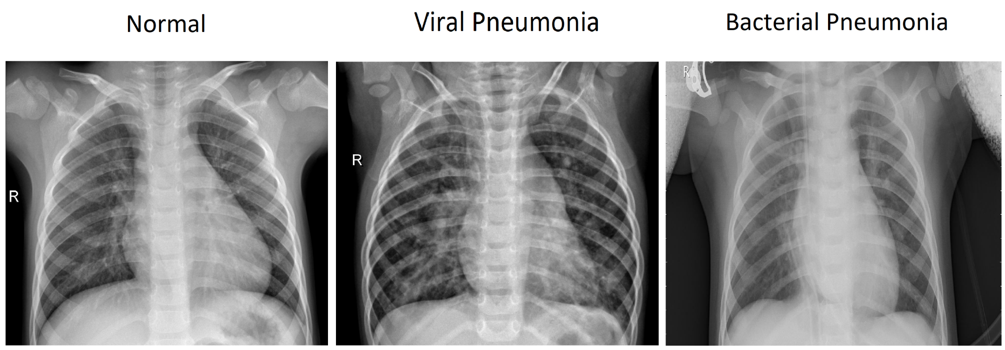


Fig. 1. Examples of Viral Pneumonia, Bacterial Pneumonia and Normal Chest Samples via X-ray Images.

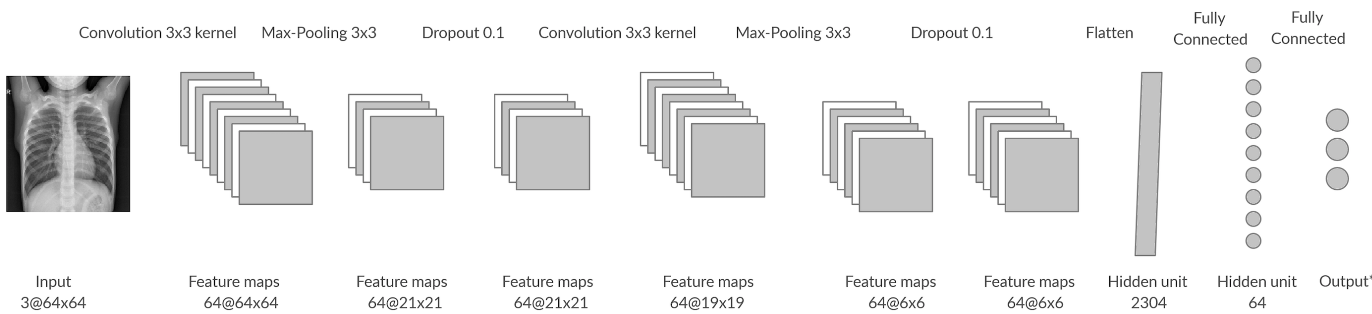


Fig. 2. A Convolutional Neural Networks Architecture for the Classification Tasks. "*" denotes the Number of Output Neurons depends on the Classification Tasks (if the Binary Classification Task needs One Output whereas, for the Classification of Three Classes (the Normal Sample-Viral Pneumonia-Bacterial Pneumonia, the Network Produces Three Output).

TABLE I. Information on X-ray Image Dataset [25]

Class	**Bacterial**	**Normal**	**Viral**	**Total**
Samples	2780	1583	1493	5856

the input for all problems and the output is to predict the label of the input which indicates the normal, absence, or presence of viral and bacterial pneumonia.

To compare the difference of the CNN performance on the size of images, we test both images of 64×64, 96×96, and 256×256. The purpose of using two various sizes of images is to investigate the performance of Convolutional Neural Networks for classification tasks. We need a good model for explaining the predictions with LIME and Saliency maps.

B. *Convolutional Neural Networks and Settings*

The architecture of Convolutional Neural Networks includes two Convolutional layers containing 64 filters of 3×3 for each layer, followed by a Max-Pooling of 2×2 (stride 2), a dropout rate of 0.1 and a Fully Connected layer with 64 neurons. The architecture is illustrated in Fig. 2. For binary classification tasks, we set the number of neurons in the output layer to 1 with a $sigmoid$ activation function. Otherwise, the output for classifying patients, viral pneumonia, and bacterial pneumonia is shown in Fig. 2 with three neurons. For multi-class classification, we use the softmax activation function.

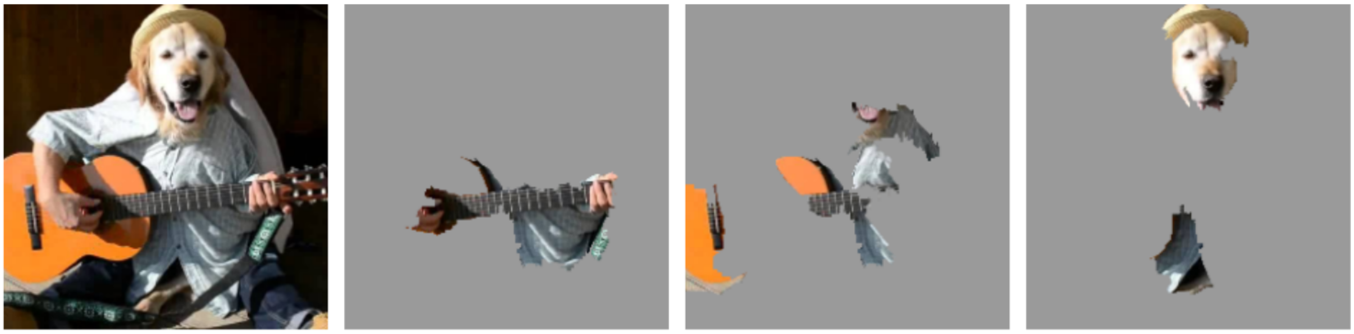
The considered CNN is carried out with Adam optimizer [26] as the optimized function with standard parameters. The cross-entropy loss is also implemented for optimization purposes. We used the default learning rate of 0.001. During training, if the loss is not improved after every 5 consecutive epochs, the training section will be stopped by the Early Stopping method and the model with the lowest validation loss will be saved.

IV. Local Interpretable Model-Agnostic Explanations

The LIME method can explain the predictions of any machine learning models, the main purpose of this technique is to understand the model by perturbing the input and understanding the change of the predictions. More specifically, LIME visualizes the contribution of each feature to the prediction from the input, it also allows determining which feature changes will affect the prediction mostly. The explanation of an input x can be obtained by the formula 1 [23].

$$\xi(x) = argmin_{g \in G} \mathcal{L}(f, g, \pi_x) + \Omega(g) \quad (1)$$

The authors in [23] denote $g \in G$ as an explanation, $\Omega(g)$ is a measure of complexity of $g \in G$. $f(x)$ is the score of the



(a) Original Image (b) Explaining *Electric guitar* (c) Explaining *Acoustic guitar* (d) Explaining *Labrador*

Fig. 3. An Example of the Explanations of an Image which Predicted by Inception Neural Network [23], [27].

relevant class. $\pi_x(z)$ is only found with respect to a proximity measure in the neighborhood of x. The $\mathcal{L}(f, g, \pi_x)$ is responsible of g to f while a low loss is desirable indicating high local fidelity. An example of LIME explanation is illustrated in Fig. 3 [23]. Fig. 3a contains the original image whereas Fig. 3b, Fig. 3c, and Fig. 3d display the explanation for $ElectricGuitar$ class, $AcousticGuitar$ class, and $Labrador$ class respectively.

We also applied Saliency maps to our CNN for discriminating the features in images. Saliency maps offer a visualization of somewhere in the image that the model pays attention to and contributes the most to predictions. Saliency maps are usually visualized as a heatmap where the highlighted pixels are the important points that affect the decision of the model. Fig. 4 illustrates the important regions within an image that contribute the most to the output, by calculating the gradient of a class output concerning the input image via back-propagation.

V. Experimental Results

A. Metrics for Comparison

The performance of the model for classification tasks is evaluated by computing the average accuracy on 10-folds stratified-cross validation. The classification accuracy is defined by the number of correct predictions divided by the total number of predictions and multiplied by 100. We also computed the Receiver Operating Characteristic Curve (ROC-AUC) for assessing the performance. ROC is a probability curve and AUC represents the degree or measure of separability. It presents the capability of distinguishing between classes of the model.

In this section, we present the results of different tasks including performance comparison on the image sizes, the discriminant performance comparison of healthy individuals and bacterial pneumonia, between normal samples and viral pneumonia samples, and exhibitions of differences of viral and bacterial pneumonia.

B. Comparison with the Different Size of Images

The chart in Fig. 5 visualizes the comparison between three sizes of images. We investigated the performance of model on both sizes 64×64, 96×96, and 256×256 for classifying three classes $Normal$, $Viral$, and $Bacterial$. The images with a size of 64×64 reached the overall average accuracy of 0.862 and 0.834 of AUC on 10-folds stratified-cross validation whereas the images classification with the size of 96×96 is slightly better (it reached 0.873 and 0.843 of accuracy and AUC respectively). However, the increment of sizes is not helpful due to the shallow architecture and it is inconsonant for the large sizes images. As a result, the overall accuracy and AUC reached 0.855 and 0.826 for the size of 96×96, respectively. The Accuracy and AUC column are horizontally stacked together, the left column represent for the Accuracy whereas the right of AUC. Fig. 6 visualizes the training and validation accuracy in 60 epochs where the learning is stopped by the overfitting issue. The initial performance is quite good, validation accuracy for the first epoch is 0.83 whereas the training validation reaches 0.74 and gets better after 10 epochs. The peak validation accuracy reaches 0.88 and is around 0.84 to 0.87.

C. Experimental Results on the Classification between Normal Samples and Bacterial Pneumonia Samples

This task, we examined the performance of classifying Bacterial and Normal classes. We trained the proposed architecture on 10-folds stratified-cross validation. The results are quite good, the average accuracy reached 0.958 and AUC of 0.988. We also plotted the Accuracy-AUC chart in Fig. 9. The explanations of LIME and saliency maps are visualized in Fig. 7 and Fig. 8,respectively. In both Fig. 7 and Fig. 8, the numbered images No. 1 and No. 2 belong to Bacterial class. Otherwise, No. 3 and No. 4 are Normal class. Furthermore, "label" in image caption means the true label of the image, we assume that 0, 1, and 2 represent for $Bacterial$, $Normal$, and $Viral$ respectively. Also, "p" in the caption of the LIME's output means the predicted label. They also describe the same thing for the upcoming Figures of LIME and saliency maps.

Specifically, in Fig. 7, the list of yellow dots in the images represents for the discriminate features that contribute to the final output of Convolutional Neural Networks. We only take the features that positively contribute to the prediction of the label for visualizing.

Furthermore, we also investigated the heatmap rendered by the saliency maps method which represents the conspicuity of the model which illustrated in Fig. 8. In the case of Bacterial pneumonia, the areas of inflammation in the lungs are pointed

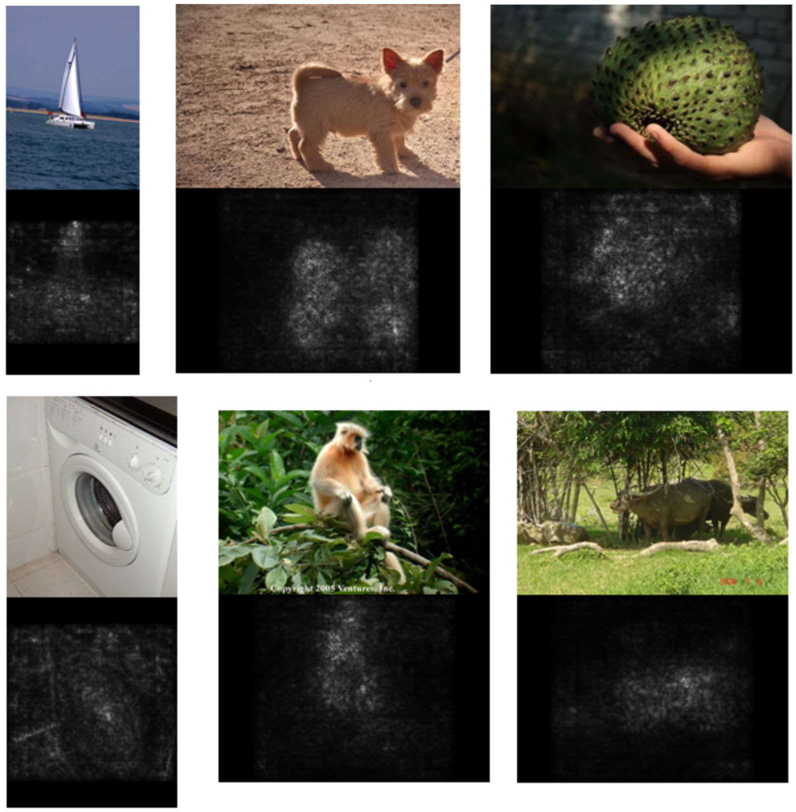


Fig. 4. Visualizations of Samples on the Image-Specific Classes by the Saliency Maps. [24].

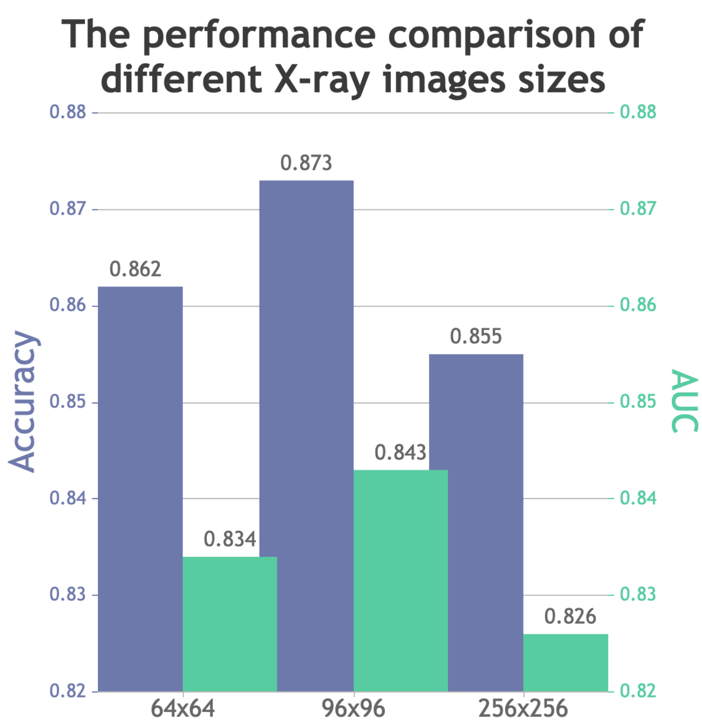


Fig. 5. Performance Comparison of Different Images Sizes on the Considered Image Dataset.

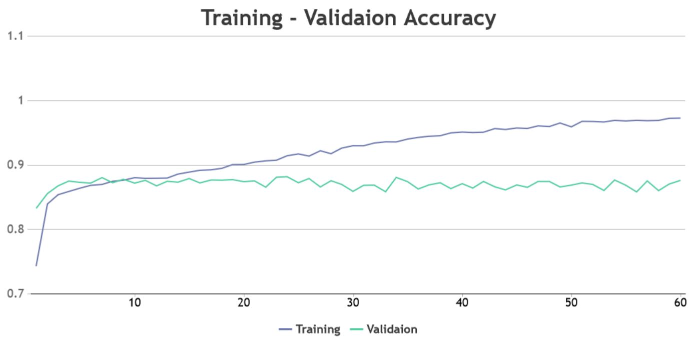


Fig. 6. Performance Visualization of Training and Validation Accuracy in 60 epochs.

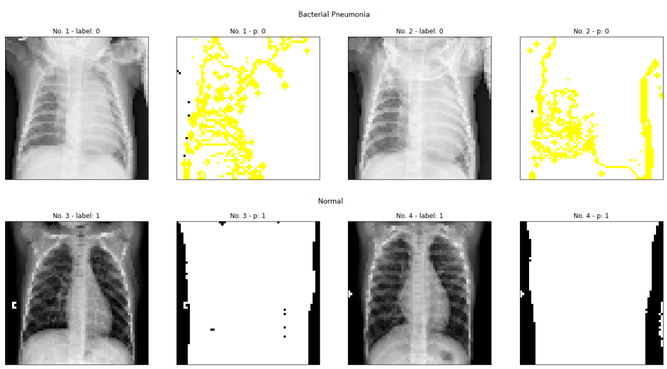


Fig. 7. The Exhibition of $Normal$ and $Bacterial$ Classes based on the Predicted Output from CNN using LIME.

out by the green bright pixels in the images. Otherwise, the heatmaps visualization presents the lungs with some noises.

D. Experimental Results on Normal Chest and Viral Pneumonia

The efficiency of classifying between Normal and Virus is quite good, the chart in Fig. 12 exhibits the average validation performance reaching 0.939 in Accuracy and an AUC of

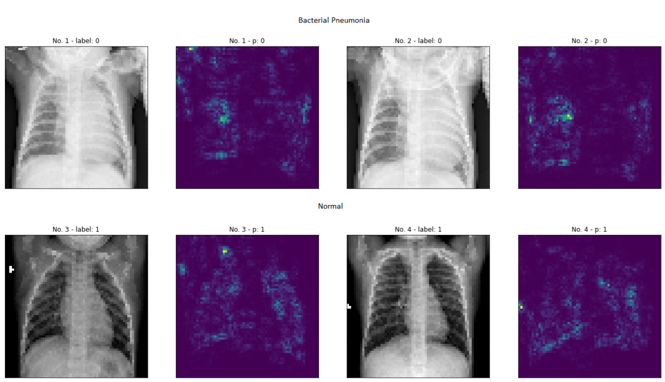


Fig. 8. Image Specific Class Saliency Maps for the Predicted $Normal$ and $Bacterial$ Classes.

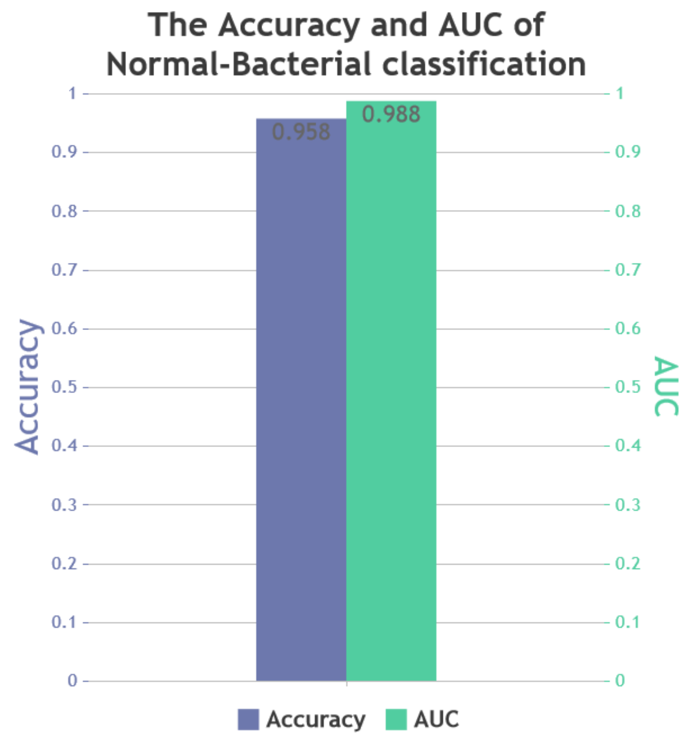


Fig. 9. The Validation Accuracy and AUC of the Normal-Bacterial Classification Task.

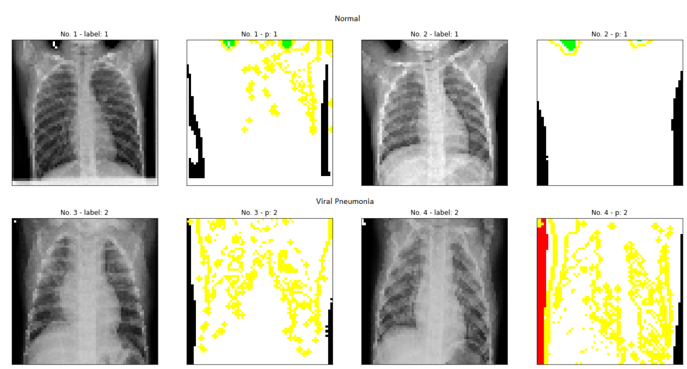


Fig. 10. The Explanation of $Normal$ and $Viral$ Classes based on the Predicted Output from CNN using LIME.

0.981. In comparison with the prior task, the performance slightly decrease. We also applied LIME and saliency maps for explaining the predicted results and visualized them in Fig. 10 and Fig. 11. As we mentioned above, the images come with "label" state their true label and "p" declare the predicted label.

The Normal images in Fig. 10 are described nearly the same with the normal in Fig. 7, the contribute features in images are different from the Bacterial. The explanations of Bacterial might provide insights into pneumonia, the abnormalities in lungs have been listed as yellow points.

Fig. 11 illustrates the highlighted features in images of Normal and Viral class by computing the gradient of output from the Convolutional Neural Networks. With Normal class,

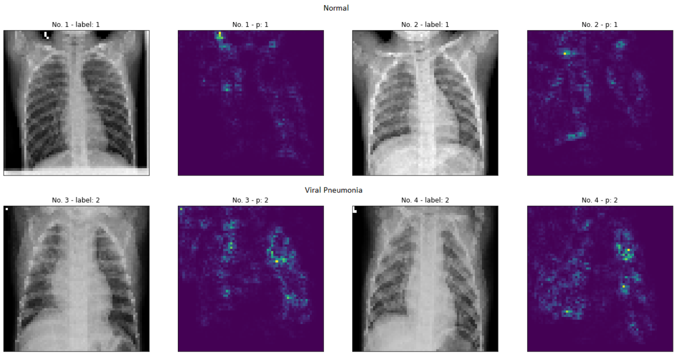


Fig. 11. Image Specific Class Saliency Maps for the Predicted $Normal$ and $Viral$ Classes.

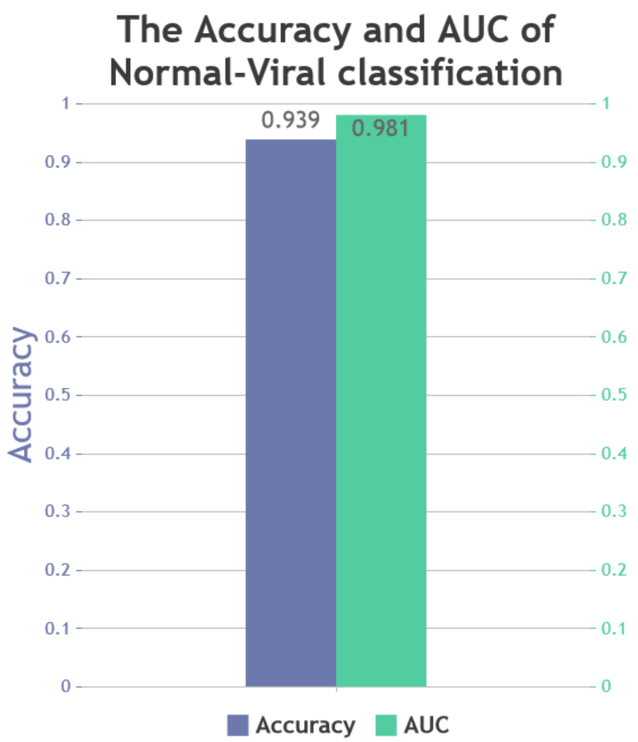


Fig. 12. The Validation Accuracy and AUC of the Normal-Viral Classification Task.

the most contributions to the final output have been around the lungs. On the other hand, the presence of pneumonia has been spotted by the superpixels.

E. Experimental Results on the Bacterial and Viral Pneumonia Classification

Bacterial and Viral pneumonia images are very similar and not easy to discriminate them. The classification performance is significantly reduced on this task due to the similarity of bacterial and viral pneumonia. Moreover, imbalanced data may influence performance. As we proposed in Section III, the Bacterial class contains 2780 images (65%) whereas the number of samples in Normal class is 1493 (35%). The validation accuracy and AUC reached 0.756 and 0.799, respectively. To handle the imbalanced classification problem, we applied the oversampling method [28]. In specific, we randomly duplicated the samples in the training set of Viral class, the number of generated images is 1200. We retrained the model with the proposed parameters, the accuracy and AUC increased slightly, 0.808 for accuracy and 0.888 of AUC. We also visualized the performance in Fig. 15. The imbalanced column represented the accuracy and AUC of the imbalanced classification. Otherwise, the Balanced column proposed the increased performance after applying the oversampling method.

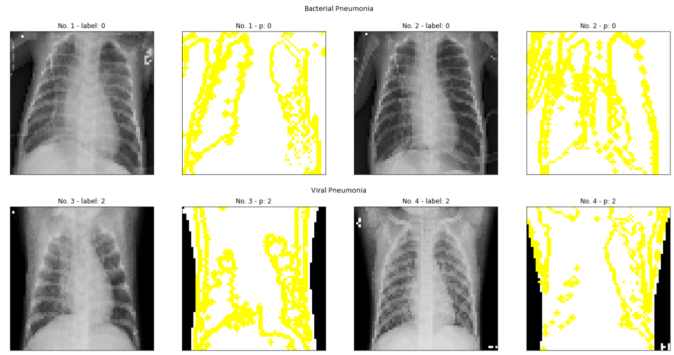


Fig. 13. The Explanation of $Bacterial$ and $Viral$ Classes based on the Predicted Output from CNN using LIME.

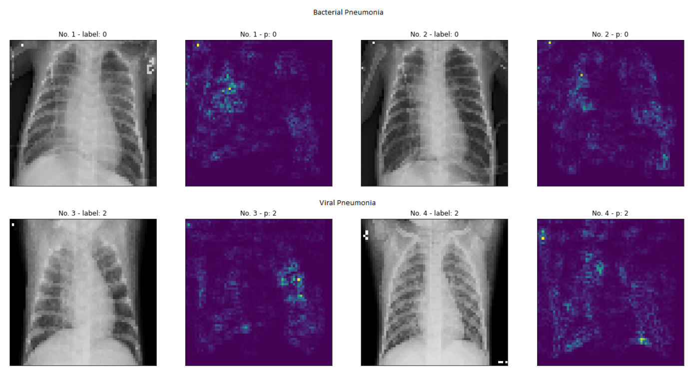


Fig. 14. Image Specific Class Saliency Maps for the Predicted $Bacterial$ and $Viral$ Class.

Fig. 13 and Fig. 14 present the discriminate features of Bacterial and Viral pneumonia which generated by LIME and saliency-maps-based method respectively. Observing the Bacterial and Viral X-ray images as non-radiologists is a challenge, it seems to be confused. The explanation of Bacterial images tends to be localized and consolidation whereas the Viral images are diffuse and interstitial markings. Furthermore, the classification performance has a certain influence on the LIME or saliency results.

We also presented the overview of three classes (Bacterial, Normal, and Viral) with LIME and saliency method in Fig. 16 and Fig. 17 respectively. The description of normal and each pneumonia type are explained as above.

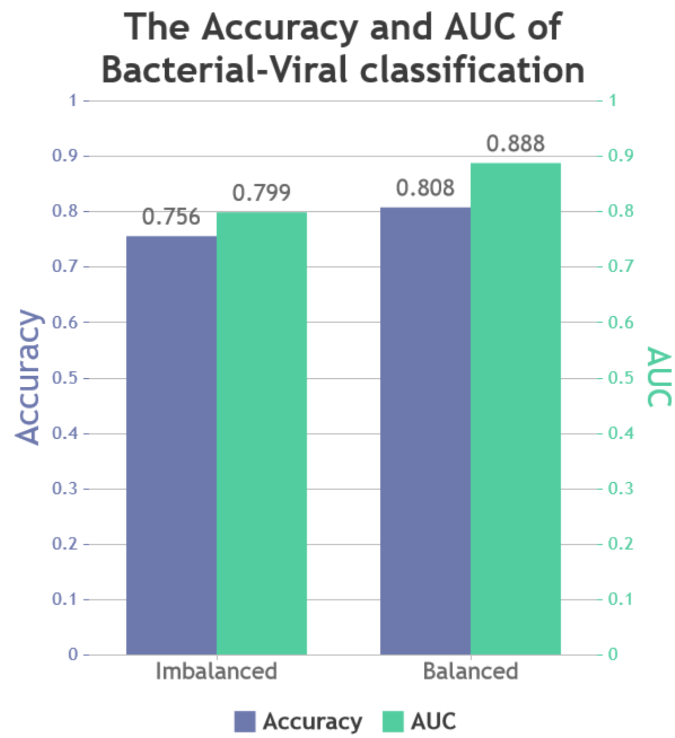


Fig. 15. The Validation Accuracy and AUC of Bacterial-Viral Classification Task for Imbalanced and Balanced Classification.

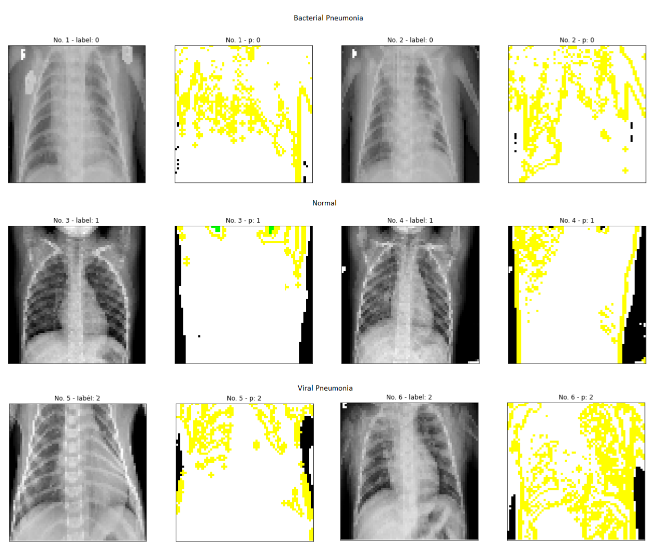


Fig. 16. The Explanation of $Bacterial$, $Normal$, and $Viral$ Classes based on the Predicted Output from CNN using LIME.

VI. Conclusion

We presented an approach to combine the convolutional neural network and model explainability to support pneumonia diagnosis. The pneumonia classification X-ray images-based have been popular in recent years, applying several machine learning techniques for explaining the predictions

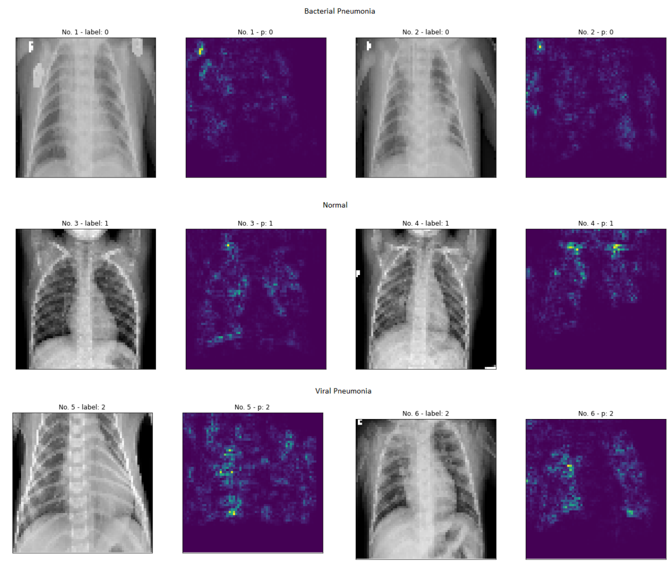


Fig. 17. Image Specific Class Saliency Maps for the Predicted $Bacterial$, $Normal$, and $Viral$ Classes.

is a promising approach. As shown from the results, the proposed method is a promising approach so that the doctors who unfortunately own fewer experiences due to some limited conditions can leverage the proposed method to improve the diagnosis accuracy and speed up the pneumonia diagnosis. In our experimental results, the performance of explanations is almost based on how good the classifier is. Moreover, the complexity of the model also influences the results of high-resolution image classification. The proposed architecture learning model has acceptable results on several tasks but with our limitations, it still challenges classifying Viral and Bacterial pneumonia. The pneumonia diagnosis with X-ray images and explain the results by machine learning are significant and play a key role in medical diagnosis.

Various sizes of images are also investigated and evaluated. In our experiments, with higher images in the same CNN architecture, the performance can be improved but the results in classification with very large images, for instance, 256×256, can be not high. The Very larger image sizes may need more sophisticated models to enhance the performance and they also require more computation resources. Due to the limitations of computation resources, we only use shallow CNN architectures with a few convolutional layers on the small images. Further research should take into account deeper architecture to enhance classification tasks.

The Oversampling technique is attempted and helps to improve the performance where we only face imbalanced images datasets. Further research can continue to investigate to find better approaches to imbalanced issues for image datasets.

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Abandoned Object Detection using Frame Differencing and Background Subtraction

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***Abstract*—Tracking objects over fixed surveillance cameras are widely used for security purposes in public areas such as train stations, airports, parking areas, and public transportation for the prevention of terrorism. Once the object is accurately detected in the image scene, we can use various visual algorithms to find a number of applications. In this paper, we introduce a model for tracking the multiple objects along with detecting the abandoned luggage in the real time environment. In our model, we used the initial frames to model the background scene. Next, we used the motion model that is background subtraction to detect and track moving objects such as the owner and the luggage. The proposed model also maintains the position history of moving objects followed by the frame differencing technique to find out the luggage history and detect the abandoned luggage by a human. We have used PETS2006 and PETS2007 dataset for the testing of the proposed system in various indoor and outdoor environments with varying lighting conditions.**

Keywords*—*Object detection; video surveillance; tracking; background subtraction; frame differencing; motion model

I. Introduction

Multiple object tracking and the detection of an abandoned object is a common and important visual-based application used in a video surveillance system. Thus, finding an accurate and efficient algorithm for the abandoned object detection is still a challenging task for the researchers. A good object detection model can improve the surveillance system and improve security to save lives.

Global security and terrorism are some of the major problems the world is facing these days. In recent years, most terrorist attacks happened in public places involving some suspicious objects which are left unattended at public places such as train stations, market places, public transport, and airports.

Human life is so precious and mean to be protected, in the observation of protection it can be classified as suspicious behavior of a person like attempting to attack or though the unattended dangerous objects like suspicious baggage detection in public places. These terrorist attacks have highlighted the need for the video surveillance systems at public places and guarded 24 hours round the clock.

In this situation, it is important to introduce and deploy an autonomous visual-based model [1], [2] to detect the unavoidable activity that can recognize suspicious activities in public areas. Mostly the threat is generated from the unattended or left luggage in the public area, See Fig. 1.

Various research studies conducted on this area to make video surveillance [3] more versatile and reliable but the detection of suspicious objects is still a challenging job in video surveillance. We need a system that distinguishes and identify highly hazardous situations and makes alerts to take proper action.

Fig. 1. Unattended Luggage. The Left Figure Shows the Person is with the Luggage. The Right Figure the Person Left the Luggage Unattended. Source: PETS2007.

In this research paper, we introduce a general visual-based framework that autonomously detects the unattended baggage in forbidden areas. Our model detects and tracks multiple humans with luggage and for a period of time. As the human leaves the luggage, the proposed model detects the left luggage and mark it unattended luggage.

II. Related Work

In the left luggage scenario, we need to localize the abandoned objects and also classify them. In this section, we will discuss the existing literature about the abandoned object.

Li et al. [4] used the long and short term Gaussian mixture model in the RGB color space to build two binary foreground masks. The radial reach filter (RRF) model used to refine the mask and control the illumination changes. For identifying the left luggage, they used the linear SVM classifier, the histogram of oriented gradient (HoG) for the feature extraction, and the width and height ratio of the object.

Filonenko et al. [5] proposed a sequence of dual background difference (SOBD) model which is achieved by differencing the intensities of the current and the referenced background model to find out the static pixels in the image scene. An object detector is later integrated with the clustering method to identify the unattended luggage.

Hassan et al. [6] generated an illumination free template and proposed a tracking method to detected and track the left luggage in the public area. The intensity values were used to generate a binary mask containing all the moving objects of the scene. They tracked the binary blobs and extracted the static pixels with the help of the centroid-range. Laplacian of Gaussian filter is later applied to the current and background frame including the static regions of the frame to get the high-frequency components. The total energy is computed for both the current frame and the background frame to make sure the illumination change does not participate in the segmentation. Finally, they recorded the edge map and perform tracking with the use of a correlation matching method.

Jadhav et al. [7] used a monocular camera to detect the unattended objects in a video surveillance environment. They modeled two backgrounds transient and permanent backgrounds. Both backgrounds were defined as a Gaussian mixture model (GMM) and subtracted from the current frame to receive two binary backgrounds. They also applied the shadow removal algorithm to get the real shape of the foreground object. Later they used size, height, width, and color features to classify the extracted object. The output is the abandoned object.

Sirisha et al. [8] used a background subtraction algorithm and mixture of Gaussian (MOG) to produce the long and short term foreground models. A backtracking mechanism used to identify the owner of the luggage. The hardware ARM 7 microcontroller, buzzer, and GSM used to generate alerts. The PETS 2006 and AVSS 2007 dataset used for the experiments.

Foggia et al. [9] proposed a technique to detect the motionless objects in the video sequence. The method encoded the spatio-temporal information into the heat map. The heat map carries all the information about the tracking object in a video instead of updating the background by evaluating the movement of the objects. The experiments performed over two well-known datasets and the acquired results were compared with the state of the art methods to confirm the robustness and efficiency of the proposed system.

Lin et al. [10] used a double Gaussian Mixture Model in the RGB color space, the space was able to receive the two binary foreground masks. They refer to the two Gaussian Mixture Models as long and short term models. The proposed Radial Reach Filter (RRF) method refined the foreground masks and reduced the illumination changes. Later, they used a descriptor Histogram of oriented gradient (HoG) with a linear support vector machine (SVM) in order to recognize the left luggage. The authors generated their own datasets PETS2006 and PETS2007.

Bhargava et al. [11] brought a technique to avoid terrorism and to strengthen the global security issues with the significance of unattended baggage in mass transit areas. They described the algorithms to recognize four events that kept track of the activity. The algorithm identifies the owner of the unattended luggage based on the position history of the objects. The long absence of the owner from the image identified the status of the left baggage.

Grzegorz Szwoch [12] proposed a method to identify the stationary objects in the images. The method separates those objects from the static background that remained motionless for a long time. The image's stable pixel values in a time of the foreground regions are used to a build relationship with the movable objects. Firstly, the model tests the pixels stability belong to the moving target object based on vectors.

In the next stage, the model extracts the image regions with the cluster of stable color and brightness and related contours of the detected objects. The false contours belong to the object removed from the background. The Author presented a complete framework for the unattended baggage detection to use it in the event detection. The experiments showed the validation of the methodology.

Lin et al. [13] brought improvements in a method to detect suspicious stationary objects in images. The proposed machine model addresses the abandoned object in an image through the extraction of foregrounds and Stationary foregrounds for the real-time monitoring systems.

A. Frame Differencing

The frame differencing is the technique, we use to detect motion and find out the moving objects and stationary objects in the image scene.

Nishu Singla [14] proposed a frame differencing technique is an algorithm to observe the motion in the image scene and detect the moving objects using a fixed surveillance camera. In this technique, the model captured the image from the static camera and sequence of image from the camera stream. In the second phase, the absolute difference is calculated between the consecutive frames and the record the difference. Finally, the image processing techniques are applied to remove the noise.

Gupta et al. [15] in his work suggested three methods to find motion in the image scene. The background subtraction, frame difference, and self-organizing background subtraction (SOBS) to detect the moving object in the video frames.

Thapa et al. [16] used a background subtraction technique to detect moving objects and perform segmentation. They achieved the detection and segmentation using the differencing and summing algorithm. The method has low computational complexity to work in the real environment.

In this paper, we proposed a reliable algorithm to detect motion and find humans in the surveillance video stream and identify the left luggage. We used the background subtraction technique to detect motion and find the new objects appearing in the image scene. Additionally, we used the frame differencing technique to find out the status of the detected object by calculating the tracking motion history that helps to mark them as left luggage.

III. Proposed Methodology

In the proposed algorithm, we use the initial frames to build the background model to use it later for finding the history of the position of the new object and identify the abandoned objects.

After learning the background, the model detects the new objects in the observed scene using the reference background model against the new frames. We use the frame differencing technique to detect the new objects in the scene. Once we have the new objects, we extract them from the image frame and record their central position. Next, we need to classify the detected new objects into moving or stationary objects. For the classification, we record the new object position and keep them tracked. If the tracked object position remains stationary or unchanged for more than 100 frames we classify the object as an abandoned object otherwise moving object. The block diagram gives a review of the proposed method with various steps in consecutive order, See Fig. 2. We describe the details of each step in the succeeding sub-sections.

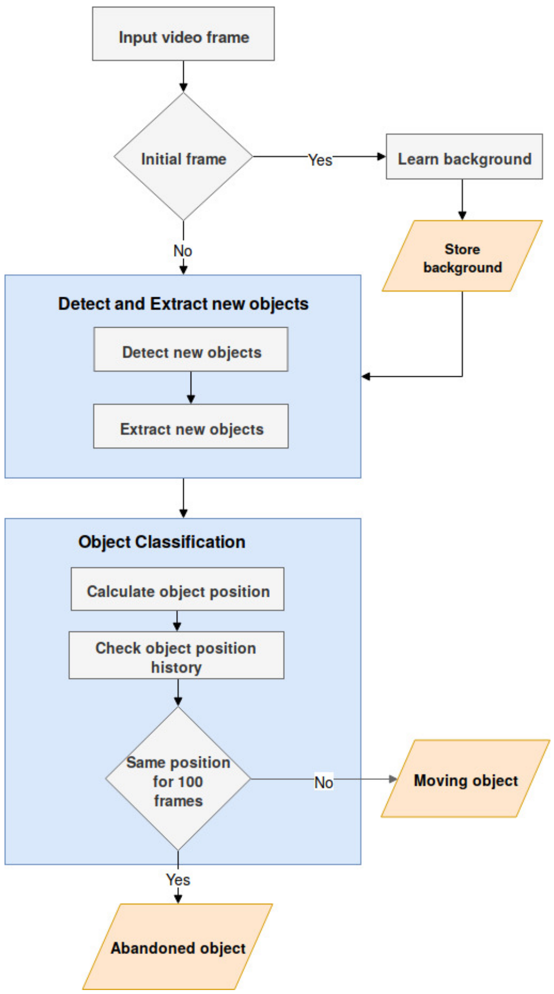

Fig. 2. The Proposed Method Block Diagram. The Method Consists of Input Frames to Build the Background Model. Later the New Object is Detected and Tracked in the Image Scene using Frame Differencing and Background Subtraction. Next, we do Object Classification whether the Object is Moving or Static based on Computing the Object Position History. Finally, we Mark or Declare the Static Object as the Left Luggage or Abandoned Baggage based on the Position History.

A. Pre-processing

The preprocessing is a necessary and standard step used generally in every machine vision algorithms. This will help to remove the noise in video frames to avoid false detection and improve the performance of the algorithm.

In the proposed method, we first resize and crop the input image to discard the unwanted pixels. Next, we convert the image into grayscale followed by the Gaussian filtering to smooth the image and suppress the noise.

B. Background Model

After preprocessing the frames, we apply the background learning technique to build the background model to enable the proposed technique to detect the moving objects when it appears in the image scene and keep them tracked. The proposed algorithm detects and tracks multiple objects simultaneously.

The background learning module takes the initial input frames and uses them to build a background model, we use the background model as a reference model to detect motion. After this step of learning the background model, we feed the frame to the next phase of the algorithm to detect and extract the new objects in the image scene.

C. New Object Detection and Pre-processing

Detecting the new objects in the image scene is an important step in the proposed technique. First, the proposed method learns the background from the initial frames later it checks the presence of the new objects using the frame differencing technique.

The detection of the newly appearing objects in the image scene works on frame differencing method. We use the background model as a reference model and difference with the new frame to find the motion and new objects. And if the object is found it status would be either static condition or moving.

This method works on the pixel-based difference of the frames to find moving or static objects based on the computed position history explained later in the sub sections.

D. Object Classification

Next the proposed method classifies the newly detected object into static and moving objects based on the computed position history of the objects. With the tracking and detection of the new objects, the proposed method also computes the position of the detected objects, the method also stores or save the object position.

The frame differencing method help to find the motion in the image scene that ultimately detects objects after that, we calculate the centroid of the detected objects and store the centroid position. We repeat the process of every upcoming new frame and check the position of the centroid. If the centroid position of the detected objects remains stationary or unchanged for the number of frames, we classify them as static objects otherwise we reset the position counter and declare as the moving object.

E. Identifying the Abandoned Baggage

After calculating and saving the position history of the objects, the object is classified as a moving or static object based on the position history.

The next step is to declare the static object as the abandoned baggage. If the object remained in static condition for the threshold of 100 frames, it would be declared as abandoned baggage or abandoned object detection. The static object is marked as drawing the red bounding box around it and marked as left luggage.

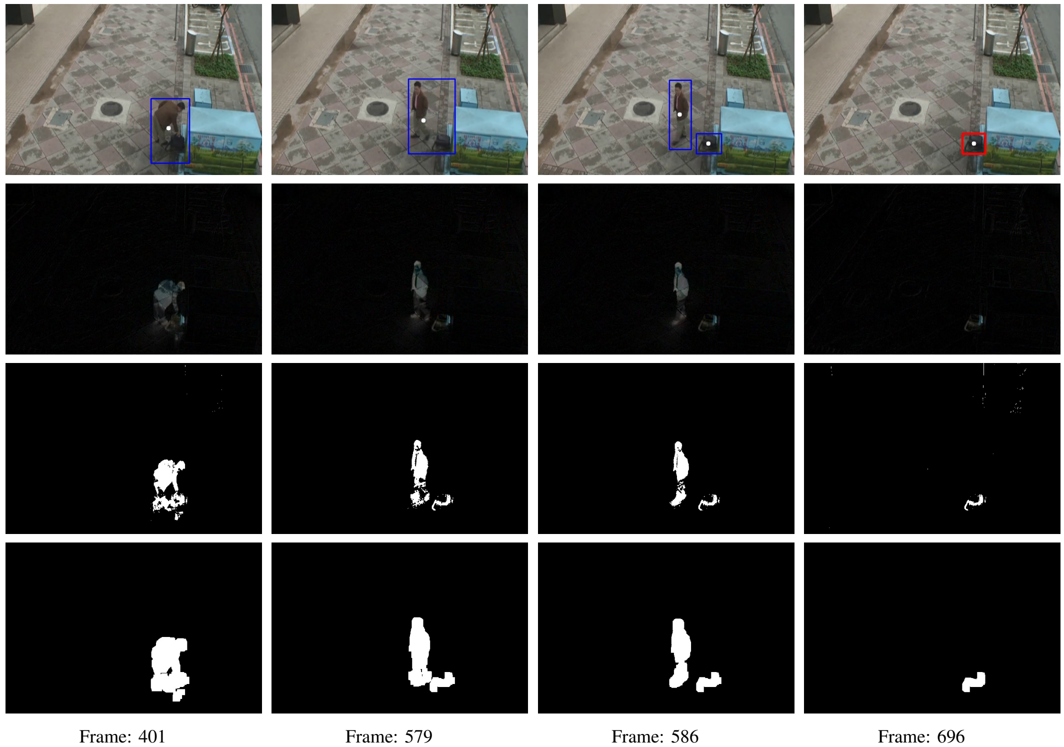

Fig. 3. The Abandoned Baggage Detection in Video Dataset I. The Results of the Sequence Video-1 with the Scenario of Street View. In the First Column, the Blue Rectangle shows the Moving Object with the Baggage. In Column Two, the Proposed Method Considers the Moving Human and the Left Baggage as One Object. In the Third Column, the Left Baggage is Detected as a New Object and Draw a Blue Rectangle and Record the History of the Position of the New Object Detected. After Some Time in the Fourth Column, the Baggage is Declared the Left Luggage and Rectangle in Red based on the Basis of the Position History of the Baggage.

IV. Experiments and Results

In this section of experiments and results, we detail the experimental setup we carried to testify the proposed methodology. We used various datasets to test the robustness of the proposed methodology. The first experiment is carried on different video datasets and showed the method successfully detected the abandoned baggage.

The dataset of [10], we used for the detection of moving objects and Abandoned objects. Videos containing different objects like people, bikes, bags, or suitcases in different environments.

A. Experiment I

In experiment I, we used the dataset [10] where the video was recorded in the street and an outdoor environment. In the video, the person appears in the scene and keep on walking in the field of view, the person also moves off the image scene and reappears in the scene after some time to make the dataset more challenging and fairly tested the robustness of the proposed methodology. The method detects a person as a moving object and draw a blue bounding box around him and keeps him tracking.

In the same video dataset, another person appears in the scene with carrying baggage and after walking a little, he left his baggage in the scene and walks away. After some time the bag was detected successfully as a left luggage and shows a red bounding box around it. When the person came again into the scene it detects him again and draws a bounding rectangle around him, see Fig. 3.

The first column shows the moving object with the baggage, the algorithm draws a blue rectangle around the moving object. In column two the moving object human left the baggage and do not move away, our system still considers them as one object. In the third column, the left baggage is detected as a new object and draw a blue rectangle. Our proposed method also records the location of the detected objects in this case the location of both human and left baggage is stored. After some time in the fourth column, the baggage is declared the left luggage and rectangle in red based on the location history of the baggage. In the last column, the object reappears in the image scene and the proposed system detects it back, see Fig. 3.

Each row shows the various steps of the proposed algorithm applied to each frame. The first row shows the original input frame in RGB (red, green, blue) color space. In the second row of the result, we applied mask and frame differencing to detect the new objects including moving and abandoned objects. In the third row, we binarize the image to segment the image and extract the desired objects such as human and left luggage. The fourth row shows both the objects in binary form while they are separated from each other, see Fig. 3.

B. Experiment II

In experiment II, we used the video from the dataset which is captured in an indoor environment. The scene shows a front

Frame: 1050 Frame: 1279 Frame: 1428 Frame: 1797

Fig. 4. The Proposed Method Results of the Dataset Sequence Video-2 with the Scenario in an Indoor Environment. The First Column Frame 1050 shows the Two Persons Coming from Two Different Sides of the Scene and Greetings each other, the Algorithm draws a Blue Rectangle around both Moving Objects. In the Second Column Frame 1279, both Objects came Closer and had some Talk later putting the Baggage off from the Shoulder and put aside on the Floor. In Column Third Frame 1428, the Baggage on the Floor is Detected as a New Object Successfully by the Proposed Algorithm and draws a Blue Bounding Box around it. In the Fourth Column Frame 1797, the Baggage remains in the Static Condition and Detected as a Stationary Object with the Blue Bounding Box around it. After some time the Baggage is Declared as the Left Luggage and the Method draws a Red Rectangle on the Object based on the Position History of the Baggage.

view of a room, where different persons keep moving around the door. Sometimes multiple people came into the scene together while some of the time single objects are moving around the door.

After some time one person came with the bag on his shoulder and meet another person. When the bag was on the shoulder of a person, it is part of that moving object or person. While talking with the other person the method detects it as two objects in the scene and draws blue bounding boxes, then the person puts off the bag on the floor and moves away from the bag.

As he left the baggage on the floor and walks away, the proposed method detected the left baggage as a new object in the scene. When the same person came again into the scene it was detected as a new object and the baggage left on the floor was detected successfully as left luggage with red bounding box, see Fig. 4.

We show the various frames consist of moving objects and left baggage column-wise. In the first column, frame 1050 shows the two persons coming from two different sides of the scene and greetings each other, the algorithm draws a blue rectangle around both moving objects. The algorithm works efficiently on the multiple objects detection and tracking. In the second column frame 1279, both objects came closer and had some talk while the talking the person carrying a bag on shoulder, putting it off from the shoulder, and put aside on the floor. In column third frame 1428, both persons leaving the scene together having ones hand on the others shoulder, it is detected as one object because the there is small space between them to recognize as two separate objects by the system. The bag on the floor is detected as a new object and successfully detected by algorithm having a blue bounding box around it. In the fourth column frame 1797 the baggage remains in the static condition and detected as an object having blue bounding box on it. After some time the baggage is declared the left luggage and draws a red rectangle on the object based on the position history of the baggage, see columns in Fig. 4.

The key steps for each frame are shown row-wise. The first row shows the input frame in RGB (red, green, blue) color space. In the second row, we applied mask and frame differencing to detect the new objects including moving and abandoned objects. In the third row, we binarize the image to segment the image and extract the desired objects such as human and left luggage. The fourth row shows both the objects in binary form while they are separated from each other, see Fig. 4.

V. Conclusion

From the past few years, global security and terrorism are one of the major problems in the world. Terrorist attacks caused human death and most probably happened in public areas like airports, transports, and market places. In order to overcome the security issues, there is the need for automated surveillance systems probably in the public places.

We proposed a framework to detect the abandoned luggage in the public area. The proposed system is efficient to work in the presence of occlusion, noise, and affine distortion. The algorithm learns the background and then detects the moving object in the foreground through a contour-based method and draw a bounding box. The proposed method detects the left object using the frame differencing to find motion and new objects in the image scene. The method additionally calculates the detected object position, check the background history for the period of time. If the detected object centroid position remains unchanged for some time, it is detected as left luggage.

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Single and Ensemble Classification for Predicting User's Restaurant Preference

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***Abstract*—Classification is one of the most attractive and powerful data mining functionalities. Classification algorithms are applied to real-world problems to produce intelligent prediction models. Two main categories of classification algorithms can be adopted for generating prediction models: Single and Ensemble classification algorithms. In this paper, both categories are utilized to generate a novel prediction model to predict restaurant category preferences. More specifically, the central idea espoused in this paper is to construct an effective prediction model, using Single and Ensemble classification algorithms, to assist people to determine the best relevant place to go based on their demographic data, income level and place preferences. Therefore, this paper introduces a new application of classification task. According to the reported experimental results, an effective Restaurant Category Preferences Prediction Model (RCPPM) could be generated using classification algorithms. In addition, Bagging Homogeneous Ensemble classification produced the most effective RCPPM.**

***Keywords*—Classification; data mining; ensemble algorithms; restaurant preferences**

I. Introduction

With the increasing accessibility of innumerable data collections, the extraction of interesting patterns from such data becomes a necessity. Data mining involves extracting interesting and helpful patterns from enormous amount of data [1]. Classification is a well-known data mining functionality that refers to the process of generating a prediction model and using it to predict categories for new unseen samples. More specifically, classification can be considered as a three-step process. The first step commences with generating the prediction model using the "training" dataset that comprises a set of samples, where each sample is associated with a categorical class label. The classification problems can be differentiated according to: (i) the number of class labels featured in the dataset and (ii) the number of the class labels associated with each sample in the dataset. With respect to the number of labels featured in the dataset two kinds of classification problems can be recognized: binary and multi-class classification problems. In binary classification problems, the considered dataset includes only two labels, while more than two labels featured in the multi-class classification problems. Regarding the number of labels associated with each sample in the dataset, also two types of classification problems can be distinguished: single-label and multi-label classification problems. When each sample in the dataset is associated with exactly one label then we have a single-label classification process. Whilst, if several labels can be associated with one sample then we have a multi-label classification process. Several classification algorithms can be utilized to produce the prediction model for each classification problem. After generating the prediction model, the next step is the evaluation in which the performance of the generated prediction model is assessed to determine its applicability to be used for predicting class labels for new samples. Several measures can be used to evaluate prediction models effectiveness; accuracy and Area Under the ROC Curve (AUC) are the most widely used measures [2], [3]. Based on the values obtained from evaluation measures, a decision can be drawn regarding whether or not to utilize the model for future prediction. The last step in the classification process is the model usage, where the prediction model is utilized to predict class labels for new unseen data. Classification has been employed in many application domains, examples of application domains include: text categorization [4], bioinformatics [5], manufacturing [6], e-learning evaluation system [7], medical diagnosis [8], data management [9], music categorization [10] and movie genre prediction [11]. Among these music categorization and movie genre predictions or genre preferences prediction [12], [13] could be considered as entertainment applications of classification. To the best of our knowledge, no previous work utilized classification algorithms for predicting restaurant category preferences.

In this paper, a novel application of classification is introduced. Classification algorithms are utilized to generate Restaurant Category Preferences Prediction Model (RCPPM). RCPPM could be considered as an entertainment application of data mining. Using RCPPM the category of the preferred restaurant could be predicted for the user relying on his/her demographic data, income level and place preferences. This would help people to know the most suitable restaurant category for them without wasting time trying several places or searching among a huge amount of the available options. To this end: (i) a novel dataset was collected, using a survey, in order to build the desired prediction model and (ii) several classification styles, i.e. single and ensemble classification algorithms were utilized. The RCPPM is a single-label multi-class classification. More specifically, each sample (user) is assigned with a single class label (preferred restaurant category) from several available categories. It is interesting to note here that RCPPM could be utilized as a "recommender system" that suggests a set of real places to the user. More specifically, RCPPM could be linked with a database comprising real places, in a specific country, that combined with categories (class labels). The recommendation process commences with acquiring features from the user, and then the RCPPM predicts the category of the preferred place relying on the given features. After that, all the real places stored in the database and categorized as the predicted category will be presented to the user.

The remainder of this paper is organized as follows. Section II supplies the reader with the essential background to the work presented in this study. Section III shows the methodology that has been followed to generate the RCPPM. Section IV presents an overview of the main characteristics of the dataset used to generate the RCPPM. Section V presents the obtained results followed by Section VI with the conclusion of the presented work and directions for future research.

II. Background

Classification is an interesting and challenging research area. Several researchers directed their research work on applying classification algorithms to real-word problems due to the potential benefits that can be summarized by producing prediction models that can predict a solution to each instance in the considered problem. As noted in the introduction to this paper, much research work has been conducted on various domains such as medical, biological, social and entertainment domains. In order to apply classification algorithms to real-world problems, the researcher should be knowledgeable about the available classification algorithms. In this section, the necessary background regarding classification algorithms is provided to the reader. Classification algorithms can be divided into two main categories: (i) "Single" classification algorithms and (ii) "Ensemble" classification algorithms. Commencing with Single classification algorithms, where only one classifier, that generated using one classification algorithm, is used for predicting output (class label). Several algorithms are available for this purpose, the most vastly used algorithms are:

- Naïve Bayes (NB) algorithms, which generate probabilistic classifiers relying on Bayes' theorem.
- Decision Tree (DT) algorithms, which produce decision tree classifiers where none-leaf nodes represent features (input) and leaf-nodes represent class labels (output).
- Rule-Based (RB) algorithms, which generate classifiers comprised of a set of "If-Then" rules. Features (input) are presented at the If side, while class labels (output) at the Then side.
- k-Nearest Neighbor (kNN) algorithms, in which the generated classifiers are referred to as lazy classifiers, because no classification models are generated. Class labels (output) are predicted based on similarity.
- Artificial Neural Network (ANN) algorithms, which produce sophisticated mathematical classifiers that comprised of connected input/output units (neurodes) and communication channels (connections).
- Support Vector Machine (SVM) algorithms, which generate classifiers by finding a "hyperplane" that distinctly distinguishes the two classes featured in the dataset.

With respect to Ensemble classification, several classifiers cooperate together to output a more effective prediction than what can be acquired from using a single classifier. If the base classifiers within the Ensemble are generated using one classification algorithm, then the Ensemble is referred to as "Homogeneous". While if the base classifiers are produced using more than one classification algorithm, then the ensemble is called "Heterogeneous" [14]. Any classification algorithm, such as DT, NB and SVM could be used to construct the base classifiers within the Ensemble. Three fundamental methods are usually used to combine the results produced by the individual classifiers: weighted averaging, majority voting and averaging [15]. Numerous researchers provided theoretical and practical evidences that Ensemble generally produces more effective prediction than their base classifiers when they are used alone (single classification) [14], [16], [17]. The most widely used Ensemble classification algorithms are:

- Bagging, in which several classifiers are constructed in parallel, using different variations of the considered dataset. To output prediction, voting is adopted to combine results from the trained classifiers [18], [19].
- Boosting, in which several classifiers are generated sequentially, the importance of the sequential connection is to use the information acquired by one classifier to enhance the training process of the next classifier [19], [20].

In this paper, several Single and Ensemble classification algorithms are utilized to generate the desired RCPPM.

III. The Adopted Experimental Methodology

This section presents the followed methodology to produce the desired RCPPM. The first and the main step in the adopted methodology is obtaining and preparing the dataset that will be used to train the classifier. The next section describes the main characteristics of the collected dataset and the considered preprocessing. Once the dataset is preprocessed, it will be fed to one of the classification algorithms to produce the prediction model. In this study, several Single and Ensemble classification algorithms have been utilized and this will be explained in the experiment section. The last step in the adopted methodology is to evaluate the effectiveness of the generated models, in order to decide the "best" model and its applicability to be used for future prediction. In this work, accuracy and Area Under the ROC Curve (AUC) metrics have been utilized for assessing the performance of the constructed prediction models. The accuracy is a simple metric that measures the percentage of the samples correctly predicted by the prediction model. While the AUC is a robust measure to evaluate the overall effectiveness of the prediction model by measuring the area under the ROC curve which plots true positive rate and false positive rate [1].

IV. Dataset Description

This section presents an overview of the main characteristics of the dataset that were used to generate the RCPPM. The considered dataset was collected using a survey that covers person demographic data, income level and place preferences. Table I presents the extracted features, with a brief description of each. The main goal is to build a prediction model to predict the user-preferred restaurant category.

TABLE I. THE EVALUATION DATASET DESCRIPTION

Feature	Brief Description	Type	Values/Range
Age	The age of the person	Nominal	{>18, 18-25, 26-35, >35}
Education Level	The educational level of the person	Nominal	{School, Collage, B.S, Master and PhD}
Work	Indicates whether the person works or not	Nominal/Binary	{yes, no}
Income level	The income level of the person per month in Jordanian Dinar	Nominal	{<50, 50-100, 100-300, 300-500, 500-1000, >1000}
Gender	The gender of the person	Nominal/Binary	{female, male}
Place Design	The design of the place preferred by the person	Nominal	{traditional, classic, modern}
Atmosphere	The preferred atmosphere for the person in terms of quiet or loud	Nominal/Binary	{ quiet, loud}
City	The city that the person prefers when he/she wants to go to a restaurant	Nominal	{Amman, Zarqa, Irbid, Jerash}
Average Spending	The average amount of money that the person spends, in Jordanian Dinar, when going to restaurants	Nominal	{<5, 5-10, 10-20, >20}
Hang-out reason	Indicates the usual reason(s) for going to restaurants with respect to the person	Nominal *	{Reading, Dating, Meeting, Parties, Studying}
Music Kind	Indicates the preferred person's music kind in the place he/she would like to go to	Nominal	{Background, DJ, No music, Live music}
Service	Indicates whether the person prefers table-service or self-service restaurants	Nominal/Binary	{Table-service, Self-service}
Go with	Indicates with whom the person prefers to go to restaurants	Nominal *	{family, friends, co-workers, nobody}
Food preferences	Refers to the person's preferred food kind(s)	Nominal *	{fast food, American, Italian, Middle East, Chinese}
Meal	Refers to the usual meal or food category the person prefers to eat at restaurants	Nominal *	{Breakfast, Lunch, Dinnar, Deserts, Drinks}
Sitting Preferences	Indicates whether the person prefers to sit in or out in the restaurant	Nominal	{Inside, Outside}
Seating Preferences	Refers to the kind of the furniture that available in the restaurant the person prefers to go to	Nominal	{Chairs, Couches, Both}
Parking	Indicates the availability of a parking service in the restaurant	Nominal/Binary	{yes, no}
Pay Method	Refers to the preferred payment method for the person	Nominal	{Cash, Card, Both}
Free Wi-Fi	Indicates if the person prefers free Wi-Fi to be available in the restaurant	Nominal/Binary	{yes, no}
Table Reservation	Indicates if the person can reserve a table before going to the restaurant	Nominal/Binary	{yes, no}
Open After Midnight	Indicates whether the person prefers restaurants that open after midnight	Nominal/Binary	{yes, no}
Speed	Indicates whether the speed of offering service is important to the person	Nominal/Binary	{yes, no}
Children seat	Indicates if the person prefers a children seat to be available in the restaurant	Nominal/Binary	{yes, no}
Wheelchair	Indicates if the person prefers a wheelchair seat to be available in the restaurant	Nominal/Binary	{yes, no}
Place Category	The category of the person's preferred restaurant (Class Label)	Nominal	{Fine Dining, National Dishes, Café Shop (Hookah), Café Shop (Study), Picnic, Jordan Folklore, Fast Food}

*the attribute is decomposed into a set of binary attributes during the preprocessing, because several options can be selected

Restaurants are categorized into seven categories (class labels): (i) Fine Dining, (ii) National Dishes, (iii) Café Shop (Hookah), (iv) Café Shop (Study), (v) Picnic, (vi) Jordan Folklore and (vii) Fast Food. Fig. 1 presents labels distribution in the considered dataset. As shown in the figure, the distribution of the labels is imbalanced, thus a preprocessing is required to resolve this issue and generate an effective prediction model. The well-known Minority Oversampling TEchnique (SMOTE) [21] was adopted. SMOTE is considered as an oversampling technique that produces artificial minority class samples.

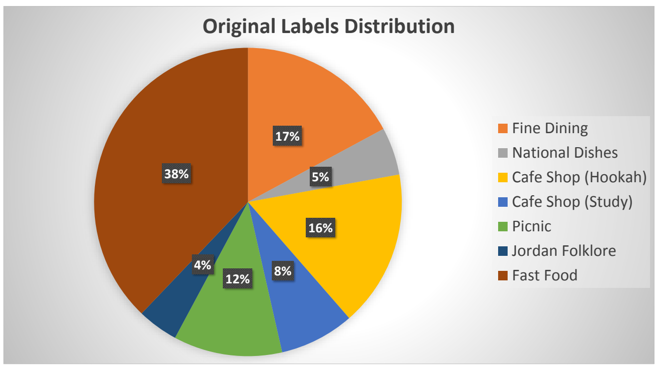

Fig. 1. Original Labels Distribution in the Considered Dataset

Fig. 2 represents labels distribution after applying SMOTE. In addition to SMOTE preprocessing, handling missing values, solving inconsistency and removing redundancy were also applied to the considered dataset. After preprocessing, the dataset features 25 dimensions and 344 data samples.

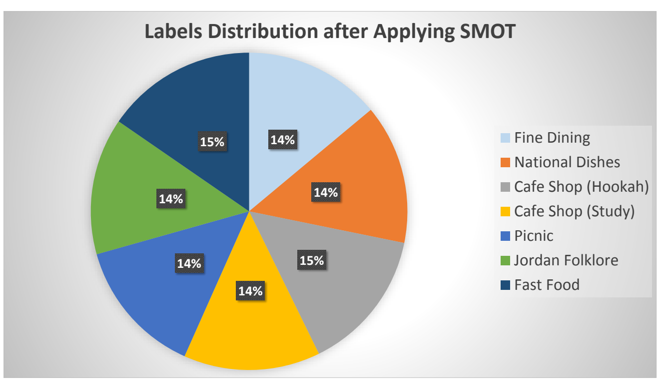

Fig. 2. Labels Distribution after Employing SMOTE

V. Experiments and Results

In this section, the obtained results from the undertaken experiments are presented. As noted earlier in the introduction to this paper, two categories of classification algorithms were utilized to generate the desired RCPPM: (i) Single classification and (ii) Ensemble classification. With respect to the first classification category; six well-known classification algorithms were used to produce the RCPPM: (i) Naïve Bayes (NB), (ii) Decision Tree (DT), (iii) Rule-Based (RB), (iv) k-Nearest Neighbor (kNN), (v) Artificial Neural Network (ANN) and (vi) Support Vector Machine (SVM). Regarding the second classification category, three algorithms were utilized to generate the RCPPM: (i) Bagging Ensemble Classification, (ii) Boosting Ensemble Classification, (iii) Heterogeneous Ensemble Classification. The well-known 10-fold cross validation technique was adopted to divide the dataset into training and testing sets and to obtain more accurate classification results. All classification experiments founded in this work were performed using the WEKA data mining tool [22].

Commencing with the results obtained from using single classification algorithms to construct the RCPPM. Table II presents the obtained results when using the six well-known classification algorithms. From the table it can be observed that DT and NB classifiers generated the same and the highest classification accuracy (Accuracy= 86.92 and AUC = 0.98).

TABLE II. Average Accuracy and AUC Results Obtained when using Single Classification Algorithms to Generate the RCPPM

Classification Algorithm	Accuracy	AUC
Simple Naïve Bayes (Naïve Bayes)	**86.9186**	**0.979**
Decision Tree (Hoeffding Tree)	**86.9186**	**0.979**
Rule-Based (Decision Table)	72.6744	0.917
k-nearest neighbor (IBK)	86.0465	0.976
Support Vector Machine (SMO)	84.0116	0.944
Artificial Neural Network (Multilayer Perceptron)	86.6279	0.961

Because the Ensemble model effectiveness is highly affected by the base classifiers [11], the Ensemble classification experiments were only conducted using DT and Naïve Bayes classifiers as base classifiers. Table III presents the obtained results from using ensemble classification to generate the RCPPM. Note here that Bagging (DT) refers to utilizing a set of DT classifiers as the base classifiers within the Bagging Ensemble to generate the RCPPM model. While Bagging (NB) refers to using Bagging Ensemble classification with NB classifiers as the base classifiers. Boosting (DT) refers to using Boosting Ensemble classification with DT classifiers as the base classifiers, while Boosting (NB) considers using NB classifiers as the base classifiers. Regarding Heterogeneous Ensemble classification, a combination of DT and NB classifiers were utilized to generate the model. Two Heterogeneous classification approaches were utilized, the first one adopts "Majority Voting" to combine results from the base classifiers, while the second one considers "Average Probability" to output the final prediction result. From the table, Bagging Ensemble classification outperforms Boosting and Heterogeneous Ensemble classification, in terms of average accuracy and AUC, for generating the RCPPM. The worst results obtained when using Boosting Ensemble classification to generate the RCPPM.

Fig. 3 presents a comparison between the performance of Single classification and Ensemble classification for generating RCPPM. From the figure, it is clearly observed that Bagging Ensemble classification outperforms Single classification algo-

TABLE III. Average Accuracy and AUC Results Obtained when using Ensemble Classification Algorithms to Generate the RCPPM

Classification Algorithm	Accuracy	AUC
Bagging (NB)	**87.2093**	**0.979**
Bagging (DT)	**87.2093**	**0.979**
Boosting (NB)	83.1395	0.952
Boosting (DT)	83.1395	0.943
Heterogeneous Ensemble (Average Probability)	86.9186	0.979
Heterogonous Ensemble (Majority Voting)	86.9186	0.923

rithms and other forms of Ensemble classification (Boosting and Heterogeneous). The reason behind the superiority of Bagging over Single classification and Boosting is the size of the considered dataset. More specifically, Bagging adopts the "Sampling with Replacement" technique to generate different variations of the dataset with the same size [1], and this technique works very well with small size datasets such as the dataset considered in this research. While the reason behind the superiority of Bagging over Heterogeneous Ensemble returns to the homogeneity of the base classifiers that can reduce prediction conflicts.

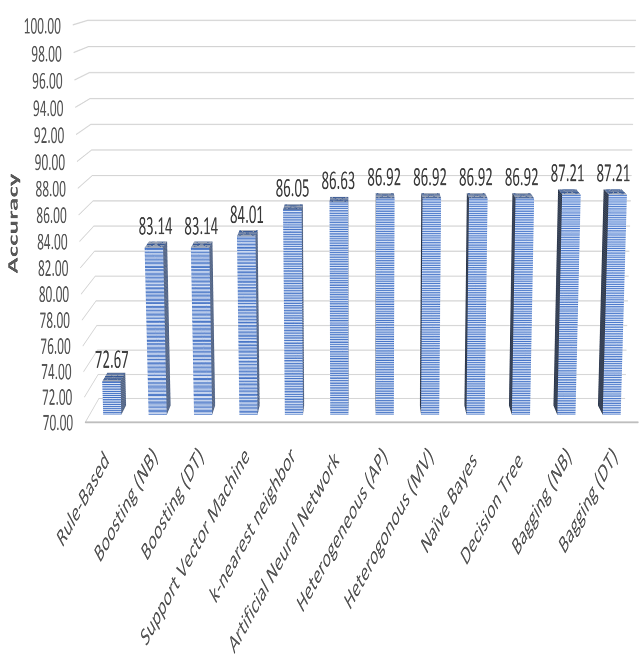

Fig. 3. Comparison between the Performance of Single Classification and Ensemble Classification for Generating RCPPM

VI. Conclusion

In this paper, Single and Ensemble classification algorithms have been utilized to generate a prediction model that aims to predict restaurant category preferences. The RCPPM is an intelligent prediction model that helps users to decide the best suitable place to go. The experiments have been accomplished using a novel dataset that covers person demographic data, income level and place preferences. From the reported experiments, supervised machine learning could be utilized to generate a high-performance RCPPM. Using ensemble of classifiers enhanced the classification effectiveness of the RCPPM. Moreover, Bagging Homogeneous Ensemble classification outperformed Single and Heterogeneous Ensemble classification. Although Heterogeneous Ensemble classification could be utilized to improve classification accuracy by using the power of completely different classifiers, it did not enhance the effectiveness of the RCPPM. The reason behind that could be the predictions conflict that generated by different kinds of classifiers. In the future, the authors plan to investigate the effect of using different features on predicting restaurant category preferences.

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A Multi-Class Neural Network Model for Rapid Detection of IoT Botnet Attacks

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Abstract—**The tremendous number of Internet of Things (IoT) devices and their widespread use have made our lives considerably more manageable and safer. At the same time, however, the vulnerability of these innovations means that our day-to-day existence is surrounded by insecure devices, thereby facilitating ways for cybercriminals to launch various attacks by large-scale robot networks (botnets) through IoT. In consideration of these issues, we propose a neural network-based model to detect IoT botnet attacks. Furthermore, the model provides multi-classification, which is necessary for taking appropriate countermeasures to understand and stop the attacks. In addition, it is independent and does not require specific equipment or software to fetch the required features. According to the conducted experiments, the proposed model is accurate and achieves 99.99%, 99.04% as F1 score for two benchmark datasets in addition to fulfilling IoT constraints regarding complexity and speed. It is less complicated in terms of computations, and it provides real-time detection that outperformed the state-of-the-art, achieving a detection time ratio of 1:5 and a ratio of 1:8.**

Keywords—Internet of Things (IoT); IoT botnets; IoT security; intrusion detection system; deep learning; neural network

I. Introduction

The dominant features of the modern era can be illustrated by the abundant data that are collected and monitored via Internet of Things (IoT) devices, as well as by the endless functionalities enabled by this innovation. As estimated by experts [1], the number of IoT devices is expected to reach 30 billion by 2020—an important development given that these widespread and convenient technologies have strongly influenced many aspects of people's lives. At the same time, however, they have also compounded the consequences of security threats. Given the innumerable IoT devices that are constantly running and accessible over the public Internet, such innovations have become an attractive platform for cybercriminals. The hack value of IoT devices is not confined to the critical information stored, collected, or monitored by these technologies but extend to any other assets that can be breached via large-scale botnets. This problem is further exacerbated by the fact that the IoT ecosystem imposes constraints on security techniques because of limited resources with respect to central processing units (CPUs), memory, and power consumption. These shortcomings render the battle against IoT botnets a critical and challenging issue.

An equally significant concern is the higher risk that IoT devices present compared with that arising from general-purpose computers. This threat stems from numerous factors [2]. First, the requirements for IoT applications are extremely heterogeneous in terms of device types, communication protocols, and operating systems. Second, the global distribution of IoT devices translates to monitoring by different parties, thereby preventing the establishment of well-defined perimeters among these overseers. From the involvement of multiple parties comes user and device mobility, which causes continuous changes in perimeters. Third, IoT devices lack strong authentication and authorization mechanisms, as reflected by the tendency of most IoT users to employ weak passwords and default account settings. Devices equipped with IoT technology usually do not require user permission or direct interaction for the installation of software or the modification of settings, thus facilitating malware propagation through application programming interfaces (APIs) and firmware. Finally, vendors experience difficulties in patching software vulnerabilities. As a result, the conventional security techniques developed for general-purpose computers, such as antivirus programs or host-based intrusion detection systems, are inadequate measures for securing IoT.

The threat model included in this study consists of attackers with no physical access to the IoT devices connected to home routers, functioning as network gateways or other middleboxes. The actualization of a threat is described as follows: An attacker needs to exploit the vulnerabilities of different IoT devices to gain access to them, but it must first discover the existence of such devices by sending probes to certain ports. The probes initially pass through a network gateway before reaching the destination. Most IoT communications are executed through cloud API services [3] instead of proceeding directly from one local IoT device to another. In this process, therefore, a network gateway occupies a vantage point from which it can inspect every network packet. The use of this point has been increasingly emphasized in the implementation of different intrusion detection techniques. Furthermore, a network gateway provides a homogeneous and lightweight defensive mechanism and policy enforcer that protects devices from being assimilated into a botnet without interrupting their normal functionality. This study focused only on the detection techniques applicable to network gateways.

Neural networks and deep learning have demonstrated promising outcomes in many fields, especially in developing accurate anomaly-based intrusion detection systems [4]–[7]. Unfortunately, they require high computational use, and it takes a long time to train a model and detect an attack. At the same time, rectifying the problem of IoT botnets necessitates specialized solutions that take into account IoT's own constraints. An adequate number of research projects have been tailored toward the detection and prevention of IoT botnet attacks using machine or deep learning. However, to the best of our knowledge and according to the provided literature review

[8]–[13], we found there were no studies considered the IoTs requirements for real-time detection and lightness while taking into account the multi-classification issue. Although, it is a critical point to recognize the attack type and then take the appropriate countermeasures to prevent any intrusions. Motivated by these issues, our study provides an independent, accurate, real-time, and lightweight model applicable to IoT gateways that is able to multi-classify the IoT network traffic. Therefore, the main contribution of this study is to adapt the fast, accurate, stable, tiny gated recurrent neural network (FastGRNN) [14] algorithm, which is dedicated to text classification, for use with intrusion detection by treating network packets as sentences and headers as words. The objectives of this study were to

- provide a model that has accurate detection of IoT botnets,
- decrease the training time,
- decrease the detection time, and
- decrease the model complexity.

We also took into account that the model is independent and would only consider the features that are directly readable by the gateway and do not require additional equipment or a third party to fetch the features and target multi-classification.

The results proved that using FastGRNN [14] provided high speed for training the model and detecting attacks, with much less complexity compared to the state-of-the-art while also preserving a high F1 score, where it attained a score of 99.04% with the RGU dataset [8] in comparison to the gated recurrent unit (GRU) model's 97.82%, and the long short-term memory (LSTM) model's 98.60%. Furthermore, the FastGRNN-based model completed its detection within 29 seconds for the entire test set for both datasets, while the model proposed by Hwang et al. [9] took 245, 249 seconds for detection.

The rest of the paper is organized as follows. Section II presents a detailed background on IoT botnets, with particular attention paid to how they operate and what destructive effects they exert. The section also introduces the FastGRNN [14] algorithm. Section III consists of a literature review and a comparison of the proposed model and the current state-of-the-art models. Section IV describes the methodology and the propose model. Section V summarizes the results and findings, and Section VI concludes the paper.

II. Background

A. IoT Botnets

A botnet basically consists of compromised devices called bots, each running malicious code under a botmaster's command and control (C&C) [2]. Specifically, a bot can propagate throughout the network. To do so, it scans the entire network ranges and exploits the known vulnerabilities or weak credentials of devices. After breaking into an unprotected gadget, the bot embeds itself into the equipment and waits for instructions from a botmaster to perform malicious activities. An example of these attacks is the collaborative flooding of a target (an IoT or non-IoT device) with numerous illegitimate requests, thus preventing the device from processing legitimate ones and causing a distributed denial-of-service (DDoS) attack. The other ill-intentioned activities of IoT botnets [2] include cryptocurrency mining, password cracking, and email spam sending, keylogging.

Although the first IoT botnet, Linux.Hydra, was discovered in 2008 [15], the security community did not realize the seriousness of this issue until the emergence of the Mirai botnet [16]. In September 2016, a Mirai attack was directed against the Krebs on Security blog, generating 620 Gbps of traffic. The availability of Mirai's original source code led to the development of dozens of variants and inspired the creation of many other botnets. For instance, the following month saw a Mirai variant take down the service provider Dyn, representing the largest DDoS attack in history. This event engendered other destructive outcomes, which were summarized by [17]. Mirai was merely the tip of the iceberg, as predicted by Vlajic and Zhou [18] and indeed we are now witnessing progressively sophisticated IoT botnet attacks with considerably more critical victims. In the same year, Rapidity Networks discovered Hajime, which has a decentralized (or peer-to-peer [P2P]) architecture in contrast to the centralized structure of Mirai [19]. The year 2017 saw a demonstration of BrickerBot's ability to permanently destroy an IoT device through a permanent denial-of-service (PDoS) attack [20], and 2018 witnessed Radware's honeypot capture JenX, which uses servers to scan vulnerable IoT devices and propagates itself within such equipment. The centralized scanning mechanism of JenX enables attackers to offer botnet-for-hire and DDoS-for-hire services [21]. Other attacks were explored by [18] and [22], who inquired into potential attacks by employing IoT as a reflector of DDoS attacks, which are very difficult to trace. Adding to our understanding of cyberattacks, Soltan et al. [23] examined a possible attack in which a botnet utilizes high-wattage IoT devices to manipulate demand and thus disrupt power grid operations. Scrutinizing the distinctive behaviors of IoT botnets plays a crucial role in endeavors to combat them. Generally, the lifecycle of an IoT botnet consists of two main phases, namely, the botnet establishment and attack launch phases (Fig. 1). These stages are described below.

1. Botnet establishment
   1.1. A bot (or malware code) implements scanning and reconnaissance to find a vulnerable device. For example, Mirai sends fingerprintable scan packets to pseudo-random IPv4 addresses to identify devices accessible via Telnet (port 23 or 2323) [17]. All communications pass through a gateway.
   1.2. The bot compromises its victim by exploiting weak credentials through brute force or the exploitation of the known vulnerabilities of IoT devices or routers [15].
   1.3. On the basis of the victim's characteristics (as the processor's architecture), a compatible version of the bot is installed and executed. Sometimes, the bot may remove any other malware and rebind ports to itself to prevent any other potential malware from attacking the victimized device.
2. Attack launch
   2.1. The attacker initiates the attack command via a (C&C) server, which then relays the required information to distributed bots. As previously stated, some botnets use P2P architecture.
   2.2. The bots begin the attack after receiving the corre-

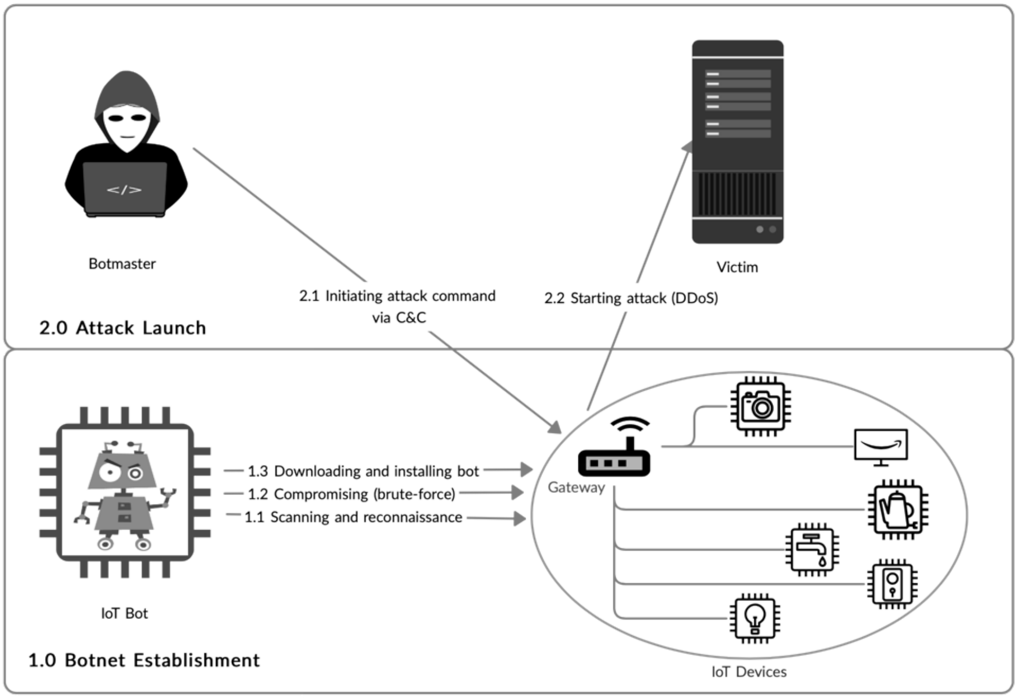

Fig. 1. The Lifecycle of IoT Botnet.

sponding commands. The attack ranges from PDoS and DDoS attacks to cryptocurrency mining and so on.

B. FastGRNN Algorithm

A recurrent neural network (RNN) is a class of neural network proposed by Jeffrey Elman in 1990 [24]. RNNs have the ability to preserve learned information from the past (or previous output) and modify it regularly with current input. This is done via a structure called hidden states, which are updated using different mechanisms or gates. A gate is simply a sigmoid neural net layer and a matrix multiplication. This ability to preserve historical data has meant that RNNs are well suited for the tasks of processing time series or sequence data, such as with neural language processing (NLP).

However, traditional RNN is prone to a vanishing gradient problem that arises when long input sequences are processed, which is the problem that LSTM [25], a different algorithm from the RNN class, was designed to resolve. The complexity of LSTM and its number of computations led to the GRU [26] which is less complicated because it has only two gates instead of the three in LSTM. Basically, GRU merges two gates, the forget and input gates, into an updated gate. In addition, it combines the cell state from LSTM with a hidden state.

FastGRNN goes further in decreasing model complexity and speeding up the learning process by adding a scalar weighted residual connection for each and every coordinate of the hidden state $\mathbf{h_t}$. As shown in Fig. 2, FastGRNN reuses the low-rank, sparse, and quantized matrices $\mathbf{W} \in \mathbf{R}^{\hat{\mathbf{D}} \times \mathbf{D}}$, and $\mathbf{U} \in \mathbf{R}^{\hat{\mathbf{D}} \times \hat{\mathbf{D}}}$ for the vector-valued gating function as well.

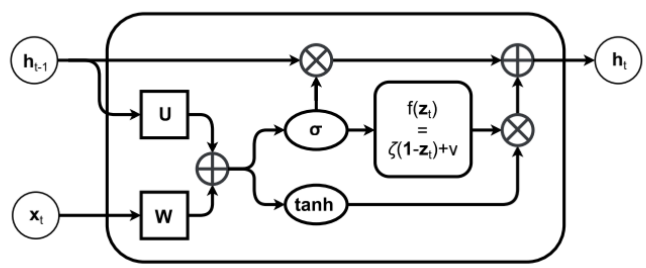

Fig. 2. FastGRNN Cell [14].

In other words, instead of directly feeding the input $\mathbf{x_t}$ and previous hidden state $\mathbf{h_{t-1}}$ into the gates or nonlinear function, these matrices squeeze those values into smaller size before passing them to the sigmoid $\boldsymbol{\sigma}$ or $\mathbf{tanh}$ function.

The learning process starts when $\mathbf{W}$ is added to $\mathbf{U}$, and the result flows into sigmoid $\boldsymbol{\sigma}$ and $\mathbf{tanh}$, resulting in $\mathbf{z_t}$ according to Equation 1 and $\mathbf{h_t}$ according to Equation 2.

$$\mathbf{z}_t = \boldsymbol{\sigma}\left(\mathbf{W}\mathbf{x}_t + \mathbf{U}\mathbf{h}_{t-1} + \mathbf{b}_z\right) \tag{1}$$

$$\tilde{\mathbf{h}}_t = \mathbf{tanh}\left(\mathbf{W}\mathbf{x}_t + \mathbf{U}\mathbf{h}_{t-1} + \mathbf{b}_h\right) \tag{2}$$

The outputs of both functions are used to calculate the final hidden state $\mathbf{h_t}$, as shown in Equation 3. Notably, $\mathbf{0} \leq \boldsymbol{\zeta}, \boldsymbol{\nu} \leq \mathbf{1}$ are trainable parameters the sigmoid function parameterizes along with $\mathbf{b} \in \mathbf{R}^{\hat{\mathbf{D}}}$.

$$\mathbf{h}_t = \left(\boldsymbol{\zeta}\left(\mathbf{1} - \mathbf{z}_t\right) + \boldsymbol{\nu}\right) \odot \tilde{\mathbf{h}}_t + \mathbf{z}_t \odot \mathbf{h}_{t-1} \tag{3}$$

III. Related Work

Anomaly detection involves the adoption of various machine or deep learning algorithms. It centers on building a model of normal behavior for a device and then leveraging the model to detect outliers that could exhibit potential attacks. Undoubtedly, deciding on appropriate features will affect the model's speed and complexity and leverage strong results in the development of considerably reliable learning models. On this basis, relevant studies were reviewed to highlight the features and how they are selected. Each study was analyzed with regard to the following criteria: detection method, whether it is multi-classification or binary, whether it is independent or dependent, whether it is real-time or offline, and whether it is lightweight or not. That information was then used as a reference in drawing the contributions of this paper.

IoTGUARD [10] observes diverse traffic types, including malicious and benign traffic, regardless of the source of flow; such traffic are fundamentally the dataset features collected from a gateway and each device log. A dataset is subjected to preprocessing steps, including oversampling and undersampling for the resolution of imbalance issues, feature extraction, analysis, and reduction techniques. Subsequently, fuzzy c-means (FCM) is used to cluster data according to self-similarities. The principal property of FCM is its ability to maintain a strong association within a cluster and weak associations with all other clusters. Weak associations facilitate task prediction because of their consideration of all clusters in determining labels for new, unknown traffic. A fuzzy interpolation scheme is then employed to ascertain the degree of malice in an attack and accordingly determine appropriate measures for various malicious traffic types. IoTGUARD has been evaluated using a dataset collected from consumer IoT devices. Aside from encompassing normal traffic, the dataset includes information on authentication attacks, botnet activities, port sweeps, port scans, spying, and worms. It achieves a high prediction accuracy with low false-positive-rate. Its operation makes minimal demands on systems because it undergoes preprocessing and reduction. However, IoTGUARD depends on features that are not directly readable and extracted via a gateway.

Concentrating on generating more relative features, Moustafa et al. [11] proposed the use of statistical features in conjunction with an ensemble method to classify IoT network traffic. To derive the features, the authors used the Bro-IDS tool [27], and to acquire specific features, they employed a novel extractor. These features consist of flow-based, Message Queuing Telemetry Transport (MQTT), and service-based characteristics, which consist of DNS and HyperText Transfer Protocol (HTTP) features. Then, the authors applied the correntropy measure to evaluate the feature set. The most important features were selected, and the unnecessary ones were eliminated on the basis of correlation coefficients (CCs). According to the correntropy results, the difference between normal and attack vectors was very small, thereby giving rise to the need to use many classification techniques, each designed on a particular kernel, like a probability, weight or feature value. Given this issue and the need to increase the accuracy of detection, an ensemble method was used along with three classification techniques: a decision tree (DT), Naïve Bayes, and artificial neural networks (ANNs). Afterwards, AdaBoost was employed to distribute network data among the techniques. The ensemble method outperformed every individual approach in terms of accuracy and detection over two benchmark datasets, namely, UNSW-NB15 [28] and NIMS [29]. However, it required more time in detecting an attack than that needed by each individual classifier, except for ANNs. Similar to IoTGUARD [10], the ensemble method is typified by statistical features that are not directly readable by the gateway and whose extraction requires another party—deficiencies that disqualify this approach as a means of online detection.

In contrast to IoTGUARD [10] and the ensemble method established by Moustafa et al. [11], the technique proposed by Doshi et al. [12] examines only flow-based features that are directly readable by most modern gateways. The dataset that comes with the approach includes classes of DoS attacks that might be generated by a Mirai-infected device; examples of such assaults are transmission control protocol synchronize (SYN) flooding, a user datagram protocol (UDP) flood, and an HTTP GET flood. The main contribution of Doshi et al.'s [12] work is feature engineering, which guides the feature extraction process. Selected features were either found in each packet's header or generated in flows from different packets. After this, evaluation was directed toward binary classification algorithms from among the following list: K-nearest neighbors (KNN), random forest, DT, support vector machines with linear kernel (LSVM), and deep neural networks (DNN). All the algorithms performed excellently, achieving an accuracy of 99%, with the exception of the LSVM, which exhibited the worst performance, possibly because the data could not be separated in a linear manner. The study also confirmed the effectiveness of neural networks despite their use with a small dataset that consisted of only 491,855 packets. The selected features are common among all protocols, indicating that Doshi et al.'s [12] proposed method is a protocol-independent technique. It supports low memory constraints because it depends on a stateless algorithm, but the accompanying dataset reflected only one phase of Mirai propagation, that is, the launch of a DoS attack. The dataset was also imbalanced, containing 459,565 malicious packets and only 32,290 benign packets, potentially adversely affecting the results.

Given that flow-based approaches suffer significant detection delay, other researchers proposed to replace flow features with packet features. For instance, Pulse's dataset [13] comprises only the attack time, the destination IP address, the protocols used, and the packets size, as well as labels that indicate malicious or benign traffic. It is a Naïve Bayes classifier that focuses on botnets' primary behaviors, specifically network scanning, network probing, and DoS. The model was built using Weka [30], which in turn, imports the dataset collected from a testbed equipped with real IoT devices. The model is better at detecting probing attacks than it is for flood-type attacks, which might be due to insufficient feature vectors. The authors [13] chose Naïve Bayes because it outperforms other methods, but they did not specify which approaches were compared and what the results were.

In like manner, McDermott et al. [8] introduced a novel approach wherein word embedding is applied on texts in network packets and fed into a bidirectional long short-term memory-based recurrent neural network (BLSTM-RNN). The main advantage of BLSTM-RNN over LSTM-RNN is its

TABLE I. THE SUMMARY OF IOT BOTNETS DETECTION TECHNIQUES.

Work	Method	Multi-classification	Independent	Real-time	Lightweight
[10]	Fuzzy C-means (FCM) clustering	✔	✘	✘	✘
[11]	Decision tree (DT), Naïve Bayes, Artificial neural networks (ANNs), and AdaBoost	✘	✘	✘	✘
[12]	K-nearest neighbor (KNN), random forest, DT Support vector machines with linear kernel (LSVM), and deep neural networks (DNN)	✘	✔	✘	✘
[13]	Naïve Bayes	✘	✔	✘	✘
[8]	Bidirectional long short-term memory (BiLSTM)	✔	✔	✘	✘
[9]	Long short-term memory (LSTM)	✘	✔	✘	✘
Proposed model	Fast, accurate, stable, and tiny gated recurrent neural network (FastGRNN)	✔	✔	✔	✔

ability to accumulate contextual information from both the past and future. The framework consists of three modules. First, data preprocessing is completed on network packets to extract length, protocol, and payload information within the info field, after which word embedding is implemented on each token and encoded into an integer format. Next, packets are normalized and unnecessary ones are removed. Second, LSTM-RNN and BLSTM-RNN models are defined and evaluated, and third, a test dataset is used to determine the effectiveness of anomaly detection. The authors also provided the dataset named Mirai-RGU, which was generated using Mirai and IoT cameras. The traffic consisted of Mirai messages between a bot (an infected IoT) with a C&C. Additionally, four attack vectors were chosen, including User Datagram Protocol (UDP) flood, Acknowledgment (ACK) flood, DNS flood, and SYN flood attacks, as well as normal traffic generated by the cameras. A couple of experiments indicated that the accuracy and loss metrics exhibited by LSTMN-RNN and BLSTM-RNN were close but favor the latter. Nevertheless, the bidirectional model added to the overhead and increased processing time.

Similar to [13] and [8], Hwang et al. [9] eliminated the time required for accumulating network packets to generate flow-based features by directing attention exclusively to the headers of individual packets. At the same time, the authors avoided the high cost of deep-packet inspection required by [8]. The central advantage here is that packet header fields are directly readable by gateways once they arrive, thus facilitating real-time detection. The authors put forward the application of word embedding on an incoming network packet to extract its semantic meanings, then adjusting three layers of LSTM to classify the packet as normal or malicious. To evaluate the model, a dataset called Mirai-CCU collected besides Mirai-RGU [8] and ISCX2012 [31] dataset. Primarily, the performance is affected by word-embedding and attack representation in the dataset. Unfortunately, the size of the input data exceeded the size of flow-based features. Thus, the time required for training was higher than usual, reaching 17 hours at 200 epochs on some datasets.

As discussed in this section, a growing body of the literature has recognized the importance of developing machine or deep learning models to detect IoT botnet attacks. These efforts are confronted with critical challenges that also point to gaps in this prominent research area. Distinctly, most proposed mechanisms focus on accuracy and disregard the analysis of other important metrics, such as algorithmic complexity and speed. Thus, this study proposes a lightweight model that provides real-time detection. Table I shows the proposed model in comparison to the current state-of-the-art.

IV. METHODOLOGY

The proposed classification model follows the same principle as in [9]. Thus, it treats each packet as a single sentence and each packet header field as a word because the stringent order of fields serves as a grammar rule, which is in essence creating sentence patterns for benign or malicious traffic. Therefore, word embedding is used to derive the semantics and syntactical features of packets. In the following subsections we will discuss dataset selection, feature extraction, dataset sampling, input preprocessing, proposed architecture, and experimental setup.

A. Dataset Selection

The effectiveness of neural network or deep learning models hinges primarily on the quality and size of a dataset. Research on IoT security suffers from the absence of benchmark datasets, but recent endeavors have been initiated to publish datasets meant to overcome this issue. Nevertheless, certain drawbacks remain. For example, the effectiveness of the dataset put forward in [33] is impeded by highly imbalanced records because it has only 477 legitimate traffic samples and 3,668,045 attack traffic samples. Among these recent efforts, and for the purposes of this study, the MedBIoT [32] and Mirai-RGU [8] datasets were selected. These datasets have been selected for the following reasons:

- A variety of IoT devices were used to generate the network traffic.
- There was realism in the attacks because real botnet binary codes were used to launch the attacks.
- Both phases of IoT botnet lifecycle are covered (see Section II-A).
- There was a diversity of attacks that were launched.

The MedBIoT dataset [32] is collected from a medium-sized network with 83 physical and virtual IoT devices, including switches, light bulbs, locks, and fans. Mirai [17], BashLite [15] and Torii [34] were used to initiate the malicious behavior of botnets. In contrast, the Mirai-RGU [8] dataset was generated using two Sricam AP009 IP cameras infected with Mirai source code that initiated different attacks against a raspberry Pi.

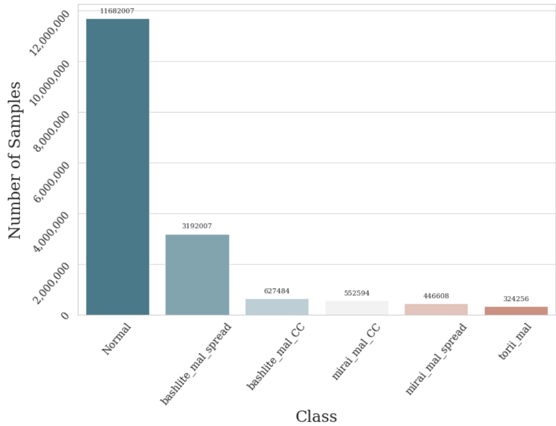

Fig. 3. MedBIoT Dataset [32] Classes Before Undersampling.

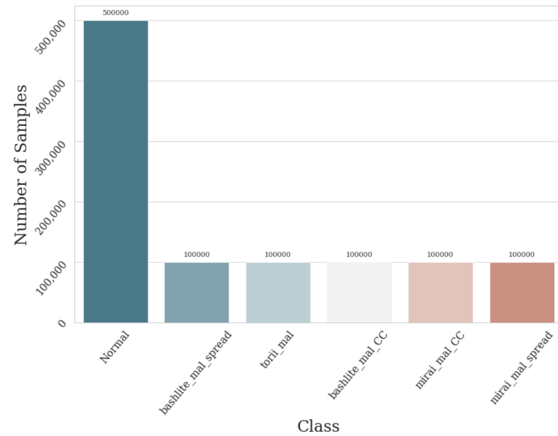

Fig. 4. MedBIoT Dataset [32] Classes After Undersampling.

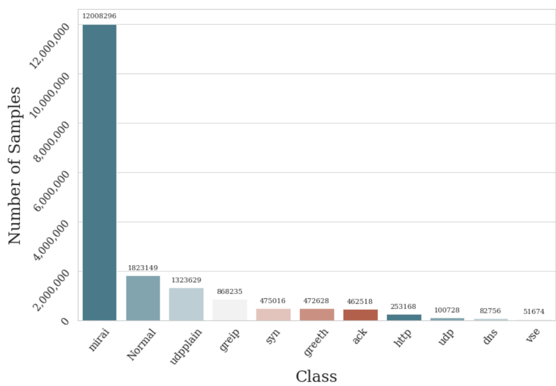

Fig. 5. Mirai-RGU Dataset [8] Classes Before Undersampling.

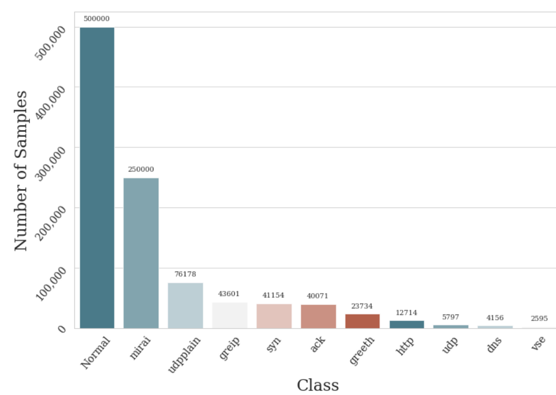

Fig. 6. Mirai-RGU Dataset [8] Classes After Undersampling.

TABLE II. PACKET HEADERS THAT USED AS FEATURES FOR THE PROPOSED INDEPENDENT MODEL.

Header	Features
Ethernet	eth_source, eth_destination, eth_type
IP	ip_version, ip_hdr_len, ip_tos, ip_length, ip_identification, ip_flags, ip_offset, ip_ttl, ip_protocol, ip_checksum, ip_source, ip_destination
TCP	tcp_source_port, tcp_destination_port, tcp_sequence, tcp_acknowledge, tcp_offset, tcp_flags_res, tcp_flags, tcp_window_size, tcp_checksum, tcp_urgent_point
UDP	udp_source_port, udp_destination_port, udp_ulen, udp_checksum

B. Feature Extraction

Both datasets consist of raw network packets as packet capture files (PCAPs). To provide an independent, lightweight, and real-time model, we needed to extract the features that are directly readable by the gateway. The required features were extracted from PCAPs using TShark [35] and converted into comma-separated values (CSVs). The extracted features were Ethernet, IP, TCP, and UDP headers, as displayed in Table II.

C. Dataset Sampling

A random undersampling technique followed to minimize the number of samples and to introduce some kind of balancing for the imbalanced classes. For MedBIoT [32], we split the dataset into two halves, normal and attacks, and then divided the attack classes equally. For the Mirai-RGU [8], we followed the attack vectors distribution of Mirai published by [17] to reflect a more realistic situation. Fig. 3, 4, 5, and 6 illustrate the undersampling effect on the classes of the datasets.

D. Input Preprocessing

Unlike LSTM-based model by [9], we did not duplicate any features. We only considered real packet headers because they require less preprocessing. To prepare a packet for embedding, all features were first converted into strings. Then, we split the dataset into training and testing sets in a ratio of 80:20, respectively. Afterward, tokenizer was applied to produce the dictionary and map each packet header with its associated integer number from the dictionary. Finally, we padded each packet to be the size of 32 words.

E. Architecture Designing

Basically, the proposed model consists of input layer, embedding layer, FastGRNN layer, dropout layer, and dense layer as illustrated in Fig. 7. First, vector of tokenized words or header fields with a size of 32 represented the input layer. The second layer was the random embedding layer that transferred each tokenized word **n** into a vector of size 64. Then, each embedded vector was passed into a FastGRNN cell with

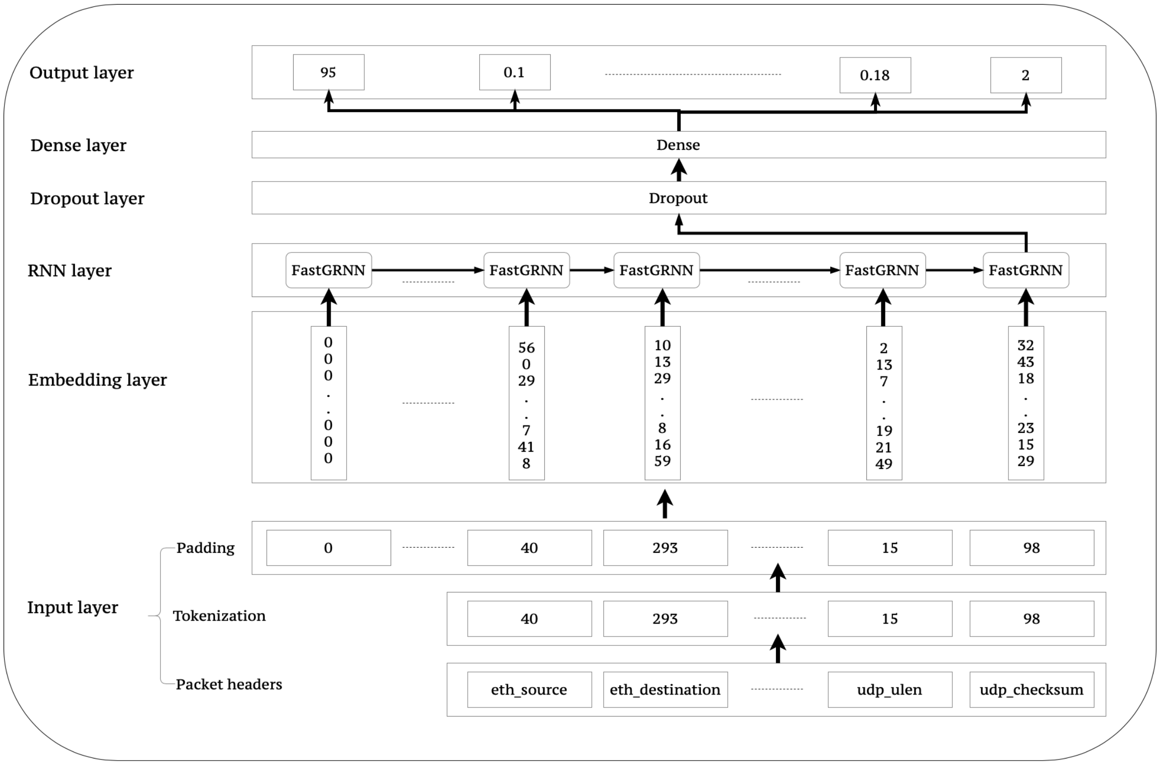

Fig. 7. The Proposed FastGRNN-based Model.

a hidden state of size 64. As mentioned in Section II-B, FastGRNN was selected due to its simplicity and lightness. Afterward, the dropout layer was used with 0.2 as the dropout rate to overcome the overfitting by dropping random neurons from the previous layer. To generate the desired output for the multi-classification task, a dense layer with Softmax as the activation function was used. Finally, to compile the model, a categorical cross entropy was used as the loss function in addition to RMSProp optimizer to adjust the learning rate.

F. Experimental Setup

The model was written in Python 3.7.3 and TensorFlow 1.15.0 [36] with Keras 2.2.4 [37]. All the experiments were done using Tesla K20 GPU, with 2496 CUDA cores and 5 GB memory besides 96 GB RAM.

V. Results and Discussion

To evaluate the model against the desired objectives, we needed to calculate the correctness of classification and the required time for training and prediction. Because both datasets were imbalanced and the model targets multi-classification, F1 score was the most appropriate metric to use. The F1 score was calculated according to Equation 4. In addition, wall time was considered when calculating the time required for training and detection. Furthermore, the model was compared with the LSTM-based model proposed by [9], but because there is no published information regarding time or the MedBIoT dataset in the paper by [9], we implemented their model and trained it ourselves. Moreover, we implemented the proposed architecture once with LSTM as a replacement for FastGRNN and called it the LSTM-based model, and then we implemented it once with GRU and called it the GRU-based model. We trained both of those architectures with both datasets, and the results are summarized in Table III.

$$\boldsymbol{F_1} = \mathbf{2} * \frac{\text{Precision} * \text{ Recall}}{\text{Precision} + \text{ Recall}} \tag{4}$$

As shown in Table III, our FastGRNN achieved the lowest training time for MedBIoT at only 1 hour, 18 minutes, and 51 seconds (1:18:51), while the second-lowest one was the LSTM-based model at 4 hours, 3 minutes, and 5 seconds (04:03:05). In addition, FastGRNN had the fastest detection speed of only 29 seconds for the entire test set, compared to the second-lowest time which was 53 seconds for the GRU. The reason the GRU had a longer training time than the LSTM is that the GRU needed more epochs to train before stopping. Actually, GRU takes about 25 minutes to complete one epoch, while LSTM completes an epoch in about 27 minutes. The LSTM-based model proposed by [9] had the slowest performance in training and detection due to using multiple LSTM layers and a large hidden states size, which makes the computations more expensive. For the F1 scores, all of the models had F1 scores of 99.99%, which might be due to the balancing of the attack classes.

Afterward, we followed another strategy of balancing classes with Mirai-RGU, as mentioned in Section IV-C. Again, the proposed model completed training within 2:0:41 while the second-fastest one, which was GRU, took 3:51:2. Also, work by [9] took the longest time to train, 10:42:38. Regarding the detection time, FastGRNN succeeded in reaching a detection time of 29 seconds, while GRU needed about 55 seconds.

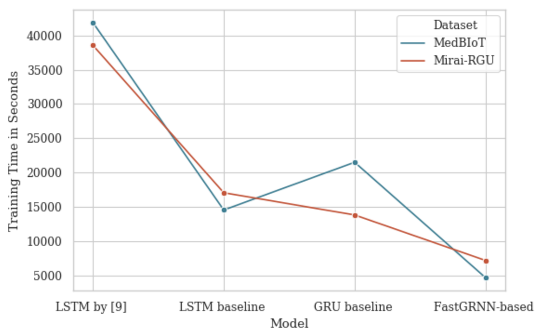

Fig. 8. The Required Training Time of The Proposed FastGRNN-based Model Compared to Other Models.

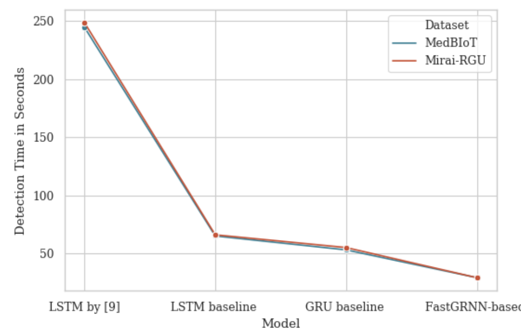

Fig. 9. The Required Detection Time of The Proposed FastGRNN-based Model Compared to Other Models.

TABLE III. Evaluation Results Of The Proposed Model On The Two Datasets Compared To Other Models.

Dataset	Model	F1 score	Training Time in hours:minutes:seconds	Detection Time in seconds
MedBIoT [32]	LSTM by [9]	99.99%	11:37:53	245
	LSTM baseline	99.99%	4:3:5	65
	GRU baseline	99.99%	5:58:49	53
	FastGRNN-based	99.99%	1:18:51	29
Mirai-RGU [8]	LSTM by [9]	99.46%	10:42:38	249
	LSTM baseline	98.60%	4:44:59	66
	GRU baseline	97.82%	3:51:2	55
	FastGRNN-based	99.04%	2:0:41	29

The proposed model outperformed GRU and LSTM in F1 score as well, with 99.04%, 97.82%, and 98.60%, respectively. Furthermore, FastGRNN achieved an F1 score close to that of LSTM. Finally, Fig. 8 and 9 illustrate the performance of the proposed model in terms of training and detection time compared to other models.

VI. Conclusion

IoT botnets are increasingly recognized as a serious worldwide cybersecurity concern. Investigating machine and deep learning is a continuing concern in relation to intrusion detection approaches against IoT botnets, but such exploration involves several issues. This study focused on developing a lightweight multi-classification neural network-based model with the aim of providing fast training time, real-time detection, and accuracy. According to the experiments, we proved that the proposed FastGRNN outperformed the other models when benchmarking both datasets by decreasing training and detection time while also preserving a high F1 score. Specifically, the proposed model completed training in 1:18:51 and 2:0:41 for the MedBIoT and RGU datasets, respectively. Detection was completed by FastGRNN within 29 seconds for the entire test set. Moreover, our model had competitive F1 scores of 99.99% and 99.04% for multi-classification of MedBIoT and RGU, respectively.

Finally, distinct technologies, along with IoT botnet detection measures, may be adopted. As future work, we will look into the opportunities engendered by federated learning. Because we aim to centralize the learning process using FastGRNN on the grounds of a fog or cloud and distributing a collection of network traffic data among several nodes or gateways, this direction would promote the application of collaborative intrusion detection approaches.

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Vehicle Counting using Deep Learning Models: A Comparative Study

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***Abstract*—Recently, there has been a shift to deep learning architectures for better application in vehicle traffic control systems. One popular deep learning library used for detecting vehicle is TensorFlow. In TensorFlow, the pre-trained model is very efficient and can be transferred easily to solve other similar problems. However, due to inconsistency between the original dataset used in the pre-trained model and the target dataset for testing, this can lead to low-accuracy detection and hinder vehicle counting performance. One major obstacle in retraining deep learning architectures is that the network requires a large corpus training dataset to secure good results. Therefore, we propose to perform data annotation and transfer learning from an existing model to construct a new model for vehicle detection and counting in the real world urban traffic scenes. Then, the new model is compared with the experimental data to verify the validity of the new model. Besides, this paper reports some experimental results, comprising a set of innovative tests to identify the best detection algorithm and system performance. Furthermore, a simple vehicle tracking method is proposed to aid the vehicle counting process in challenging illumination and traffic conditions. The results showed a significant improvement of the proposed system with the average vehicle counting of 80.90%.**

***Keywords*—CNN; transfer learning; deep learning; object detection; vehicle detection**

I. Introduction

In the earlier days before the rise of machine learning, the process of vehicle counting was done manually. It was performed by a person standing by the roadside; using an electronic device to record the data using a tally sheet. In some cases, the person may do the counting by observing video footage captured by city cams or closed-circuit television (CCTV) placed above the road or highway. According to a study in [1], manual vehicle calculation performance is 99% accurate. This investigation is based on manual calculation of various vehicles from a 5 minutes video recording. Although the manual method provides high accuracy, it requires an extensive amount of human resources. Besides, it tends to be error-prone, especially on severe traffic flow and multiple road lines. Therefore, manual calculations are usually performed with only a small sample of data, and the results are extrapolated for the whole year or season for long-term forecasts.

Vision-based vehicle detection through highly cluttered scenes is difficult. At present, this approach can be categorized into traditional and complex deep learning methods. Recently, deep learning networks (DLN) based on convolutional neural networks (CNN) have obtained state-of-the-art performance on many machine vision task. Therefore, researchers began to use it for vehicle detection and counting. In the deep learning architecture, it learns categories gradually throughout the hidden layers. For example, in face image recognition, it starts with identifying low level features such as bright and dark areas and then proceeds to recognize lines and shapes for facial recognition. Each neuron or node represents one feature and combination of those nodes will give a full representation of the image. The hidden node or layer is represented by a weight value that will influence the outcome (output), and this value can be changed during the learning process. All these layers are learned in hierarchical order and it is very crucial to determine the high-level features of the data to make an accurate decision. The overall approach mentioned has shown high accuracy in classifying objects. Zhang et al. [2] proposed a vehicle counting system that utilized a deep learning network. The system was implemented for a static image and detect vehicles in every frame. However, there is no information stated in this paper about the flow of moving vehicles.

In the literature, many works have utilized pre-trained DLN models via transfer learning methodology for vehicle detection. In [3] used a pre-trained model via transfer learning, i.e. Yolo on vehicle counting. The model is trained using the standard MS-COCO dataset. After that the researchers re-train the model on different datasets, namely PASCAL VOC 2007, KITTI and user's custom annotated dataset. The mean accuracy precision detection is around 75% achieved on an 80-20 train-test split using 5562 video frames from four different highway locations. Another research on vehicle counting was using MobileNet [4]. A MobileNet model which was pre-trained on the ImageNet dataset with a size of 224×224 pixels for each image. With a limited set of training images, the accuracy of vehicle detection was 97.4%. As for traffic volume estimates or counting accuracy at the intersections, it was 78%. There were two crucial observations in this study. First, the performance was unsatisfactory in cases of a highly overlapping vehicles such as occlusion due to partial information. The detection performance results at night or under very low-illumination conditions are also poor. In [5] proposed to use YOLOv3 Darknet-53 for vehicle detection and counting system. The results have shown that DLN can provide higher detection and counting accuracies, especially for the detection of small vehicle objects.

Following this, some studies have been conducted to compare various available CNN models as the detector for vehicle counting systems in general, such as [6] [7] and [8] to name a few. There are also studies specifically on using deep learning models for vehicle counting systems such as [9] [3] and [10]. Each study has varying results which highlighted the strengths and weaknesses of each pre-trained models. It seems that the model's performance is highly correlated with the local dataset and the characteristics of the vehicle movement. Therefore, there is no single CNN detector model that fits for all situation and providing the optimal detection result. In [8] presents a comparative study of CNN detector models using deep learning library of TensorFlow which provide portability and ease of use. They used the COCO dataset for evaluation.

The general availability of many pre-trained deep learning models might ease the implementation of an automated vehicle counting system. But the main challenge is to identify the best model from among sets of similar pre-trained models that can perform well on intended datasets. The direct comparison to determine the optimal model is difficult due to different environment settings used in experiments. Thus, a fair comparison using a similar environment for performance evaluation is needed. One possible problem with the pre-trained models performance is that the use of standard benchmark datasets for training and completely different dataset for testing. It is common experience for the user to get poor results from the query of desired objects. Thus, instead of using the benchmark datasets, one needs to re-train the model on other large custom data for networks to learn patterns optimally [11]. But, re-training on the large data can be costly and time-consuming for deployment [12]. For example, training a deep learning algorithm on huge datasets is time-consuming and computing-intensive to secure good performance results. Therefore, one possible solution is to use a pre-trained model and transfer learning for better weight scaling and convergence speed-ups. Thus, inspired by the work of [13], a set of images with different illumination is used to re-train the existing model via transfer learning. For vehicle counting, a simple method is proposed, where the coordinate locations for each vehicle are detected in every frame. The Euclidean distance is used to computed between frames of a given video sequence for tracking and trajectory estimation. A virtual reference line is constructed, and the vehicle is counted if it crosses the line.

The contribution of this paper is as follows: (1) we compare the most widely used TensorFlow's object detection model zoo, namely, Faster R-NN, SSD and Yolov3 for vehicle counting application on urban traffic volumes. (2) we demonstrate the effectiveness of using data annotation tool for vehicle detection via transfer learning. TensorFlow's detection model zoo that trains on the standard datasets such as COCO alone is not the best to describe real-world vehicle traffic conditions, but re-training the model efficiently can enhance its ability in detecting features. (3) we propose a simple vehicle counting system that uses a virtual reference line and Euclidean distance for tracking and trajectory estimations.

The rest of the paper is organized as follows. Section 2 describes the fundamental principles of deep neural network and its application to object detection. Section 3 describes our system for vehicle counting with a focus on TensorFlow's object detection model zoo with simple tracking and counting algorithms. Experimental results on the urban traffic volumes on different conditions, i.e. morning, day and night are shown and discussed in Section 4. Section 5 concludes the paper.

II. Related Work

With recent advancements in deep learning, computer vision applications such as object classification and detection can be developed and deployed more effectively. These applications have been proposed and shown significant performance improvements and enabling real-time processing of streaming data for analytic and making decision.

A. Deep Neural Networks

Deep architectures are useful in learning and have shown impressive performance for example in the classification of digits in the MNIST dataset [14]; CIFAR [15] and ImageNet [16] for object classifications. In this scheme, the lowest layer, i.e. feature detectors are used to detect simple patterns. After that, these patterns are fed into deeper, following, layers that form more complex representations of the input data. There are several approaches to learn deep architectures. One of the most frequently used in computer vision is convolution neural networks (CNNs), where the networks preserve the spatial structure of the problem by learning internal feature representations using small squares of input data. Features are learned and used across the whole image, allowing for the objects in the images to be shifted or translated in the scene and still detectable by the network. This is one of the reasons why deep architecture is so useful for object recognition such as in picking out digits, faces, objects and so on with different challenging conditions. Thus, to get a good classification result, the network is trained with a vast number of images such as using ImageNet [16] as the dataset to classify pictures. Besides the classification task, the deep architecture is widely used for object detection that draws a bounding box around each object of interest in the image and assigns them a class label. The bounding box indicates the position and scale of every instance of each object category. There are several approaches to object detection in computer vision such as Faster R-CNN, YOLO and SSD.

Typically, deep convolutional neural network models may take days or even weeks to train on huge datasets for good performance. A way to reduce the training time is to re-use the model weights from pre-trained models that were trained using millions of natural images such as from ImageNet dataset. Such a methodology is called transfer learning. In this technique, the constructed models can be downloaded and used directly, whereby a neural network model is first trained on a problem similar to the one we have chosen. One or more layers from the pre-trained model are then used in a new model trained on the problem of interest. The pre-trained model has the advantage that it is already learned a rich set of image features. Besides, the model is transferable to the new task by fine-tuning the network. In this case, the model can be re-trained on a small number of images such that the network weights are small adjusted to support the new task. Thus, it has the benefit not only to decrease the training time for a neural network model but also can result in lower generalization error. For example, in [17] use ImageNet initialized models for object detection on the Pascal VOC dataset challenge, [18] use ImageNet initialized models for semantic segmentation. Other works that utilized the ImageNet dataset for training deep learning models for image classification such as in [19], [16].

B. Deep Learning for Object Detection

In general, object detection is a task in computer vision that involves identifying the presence, location, and type of one or more intended objects in a given test image. It is a challenging problem that consists of three main processes, namely object recognition, localization and classification. In recent years, deep learning techniques have been applied to many vehicle detection problems and show promising results such as on standard benchmark datasets and in computer vision challenges.

Several approaches are using deep learning techniques for object detection. Shaoqing Ren et al. [17] proposed a method, namely Faster R-CNN to improve both speeds of training and detection of the existing Fast R-CNN [20]. The method consists of two modules, namely, (a) region proposal network, where the convolutional neural network is used for proposing regions and the type of object to consider in the region and (b) Fast R-CNN for extracting features from the proposed regions and outputting the bounding box and class labels. Faster R-CNN has proven to be efficient for object detection and secured the first-place on both the ILSVRC-2015 and MSCOCO-2015 object recognition and detection competition tasks. Joseph Redmon et al. [21] proposed an algorithm namely, you only look once (YOLO) for object detection. The algorithm is claimed to be much faster than the standard R-CNN [22] and achieving object detection in real-time. The authors then further improved the model performance and referred to as YOLO v2 [23] and YOLO v3 [24]. Another widely used model for object detection in the industry is the single-shot multi-box detector (SSD) [25]. It improves R-CNN [22] detection speed by eliminating the need of the region proposal network.

III. Proposed Method

The proposed method consists of three main steps. The first step is to detect and draw bounding boxes around vehicles for every n-frames employing transfer learning with the deep CNN architecture. The detection algorithms were inspired by the works of [17], [25] and [21] that introduced Faster R-CNN, SSD and YOLO, respectively. Next, the trajectory of each vehicle is extracted by tracking corner points through n frames. In this step, a simple method is introduced to identify the trajectory of each vehicle found in the first step. Finally, a simple counting algorithm to count the number of vehicles on the street is proposed. Details of the algorithms are as follows:

A. Faster R-CNN

As stated before, this method was proposed by Shaoqing Ren et al. [17] which aims to improve both computational speeds and the detection accuracy of existing Fast R-CNN [20]. This technique mainly comprises of two modules which are region proposal network and Fast R-CNN for extracting features from the proposed regions. Similar to Fast R-CNN, the image is provided as an input to a convolutional network which will output a set of convolutional feature maps on the last convolutional layer. Instead of using a selective search algorithm on the feature map to identify the region proposals, a separate network is used to predict the region proposals. In this case, a sliding window of size n × n is run spatially on these feature maps. For each sliding window, a set of 9 anchors are generated which all have the same centre, but with three different aspect ratios and three different scales. Finally, the n × n spatial features extracted from those convolution feature maps are fed to a smaller network which performs classification and regression. The predicted region proposals are then reshaped using a region pooling layer which is then used to classify the image within the proposed region and predict the offset values for the bounding boxes. The regressor output determines the position, width and height of the predicted bounding box. The proposed method results outperform Fast R-CNN on a detection speed of 0.2 seconds on each image. Fig. 1 shows the Faster R-CNN model architecture. In this model, ResNet101 [26] CNN architecture is used for extracting in-depth features and classification.

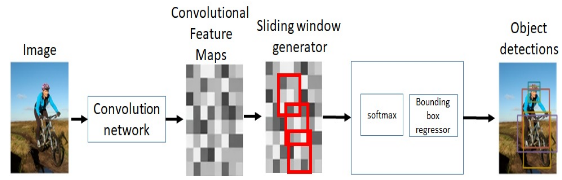

Fig. 1. Faster R-CNN Generates Anchors of Different Ratios and Scales for each Sliding Windows on Convolutional Feature Map. After that, the Output of Regressor Determines a Predicted Bounding Box.

B. Single Shot MultiBox Detector (SSD)

The SSD architecture was published in 2016 by researchers from Google for object detection in real-time [25]. It uses VGGNet convolutional neural network [19] as the base net for feature extraction. In contrast to Faster R-CNN, SSD improves the detection speed by eliminating the need of the region proposal network. In SSD, it provides a set of different default boxes with varying scales for object detection. These features (multi-scale features and default boxes) are used to recover the drop in the object detection accuracy.

Furthermore, each element of the feature map has several default boxes associated with it. The feature map sets came from different layers of the CNN network. A typical CNN network gradually shrinks the feature map size and increase the depth as it moves to the deeper layers. The deep layers cover larger receptive fields and construct more abstract representation, while the shallow layers only cover smaller receptive fields. By utilizing this information, it is possible to detect small objects in shallow layers and large objects in deeper layers. For detection, any default box with an Intersection over Union (IOU) of 0.5 or higher with a ground truth box is considered a positive sample. Fig. 2 shows the single-shot multi-box model architecture. In this model, Inception [27] CNN architecture is used for extracting in-depth features and classification.

C. You Only Look Once (YOLO)

Joseph Redmon et al. [21] proposed an algorithm namely, you only look once (YOLO) for object detection. The algorithm is claimed to be much faster than the standard R-CNN [22] and achieving object detection in real-time. In contrast to the previous schemes, YOLO uses a neural network to predict the bounding boxes and class labels for each bounding

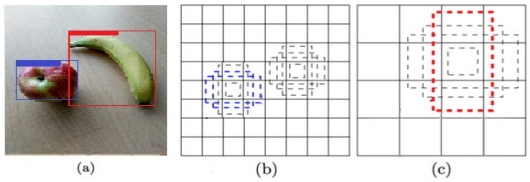

Fig. 2. (a) Original Image with Two Ground Truth Boxes, (b) Two of the 8x8 Boxes (Blue Color) are Matched with the Apple, and (c) One of the 4x4 Boxes (Red Color) is Matched with the Banana. It is Important to Note that the Boxes in the 8x8 Feature Map are Smaller than those in the 4x4 Feature Map. In Total, SSD has Six Different Feature Maps, and Each Map Responsible for a Different Scale of Objects, Enabling it to Detect Objects Cover a Large Range of Scales.

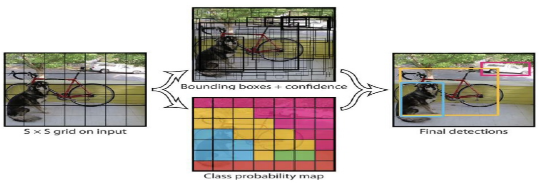

Fig. 3. Summary of Predictions made by YOLO Model. Taken from Joseph Redmon et al. in (2015) YOLO Paper.

box directly. YOLO works by taking an image and splits the input image into a grid of cells. Then, each grid cell predicts a bounding box if the centre of a bounding box falls within it. Each grid cell uses a confidence value to predict a bounding box that involves spatial coordinate x,y and the width and height of the box. For each bounding box, the network calculates a class probability value and offset values for the bounding box. The bounding boxes having the class probability map above a threshold value are then combined into a final set of bounding boxes and class labels. Fig. 3 shows the YOLO model architecture taken from [21]. In this model, Darknet [24] CNN architecture is used for exacting in-depth features and classification.

D. Vehicle Tracking

A simple vehicle tracking algorithm is proposed in this work. The process starts with converting video clips to frames. The output from the object detection model is bounding boxes with coordinates and class labels. The coordinates can be used to determine the centre point of each object and in this case, vehicles. Assuming the first two frames of a video clip is depicted in Fig. 4.

In this figure, assume that we have two vehicles at different location and frame. Here, by indicating (m_1, n_1) and (m_2, n_2) for the first vehicle coordinates in the first and second frame respectively. And (x_1, y_1) and (x_2, y_2) for the next vehicle coordinates in the first and second frame respectively. These coordinates are midpoints of the bounding boxes provided by the object detector. For example, let's say the object detector detects a vehicle in a video frame and draws a bounding box at (x_{start}, y_{start}) and (x_{end}, y_{end}), where x_{start} and y_{start} are the x and y coordinates of the upper left corner of the bounding box respectively. And x_{end} and y_{end} are the x and y coordinates of the lower right corner of the bounding box respectively. Thus, the midpoint of the coordinate

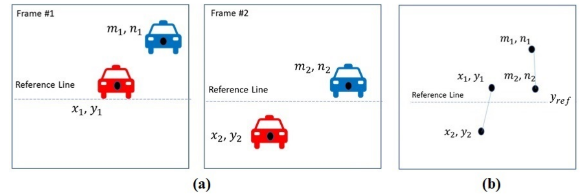

Fig. 4. (a) Sample Images from Two Consequent Frames, i.e. Frame#1 and Frame#2. (b) The Vehicle is Tracked from the Minimum Displacement from the First Frame to the Second Frame.

is $(x_{start} + (\frac{x_{end} - x_{start}}{2}), y_{start} + (\frac{y_{end} - y_{start}}{2}))$. Next, the euclidean distance is computed for each point from the first frame to the next frame resulting in four different distance values. After that the minimum displacement for each point in frame #2 is determined to obtain the nearest pair from frame #1 (Fig. 4(a)). This will result in pairs, as shown in Fig. 4 and virtual trajectory lines can be seen between these pairs (Fig. 4(b)). For counting, a reference line (dot-line) is defined in these frames, which will be used to determine if a car has passed or not to be counted in the vehicle counter algorithm.

To briefly explain the concept of the euclidean tracking algorithm suppose the number of vehicles is $\{x_i : i = 1, ..., L\}$ in the first frame and $\{y_i : i = 1, ..., K\}$ in the second frame. The goal of the euclidean tracking algorithm is to identify the nearest pair as follows:

$$TRACK(L) = \sum_{i=L} \min_{1 \leq j \leq K} ||x_i - y_j||^2$$

Thus, the tracking algorithm works by iterating from the first until all point pairs in the second frame are visited. After that, assign each observation in the first frame to the closest distance point in the second frame.

E. Vehicle Counting

The counting method is based on the vehicle regional bounding box marks and the virtual reference line. This technique assumes that the vehicle movement is in a direction. For counting, each detected vehicle in the detection step is assigned with a unique label and tracked until it reaches the virtual line. In this work, we have used five different class labels, namely bicycle, car, motorcycle, bus and truck. And all these labels are categorized as vehicle object and will be used in the counting system. After that, each vehicle position is checked whether it has crossed the horizontal reference line (y_{ref}) at the y-axis as drawn in Fig. 4(b). If it passed the line, then it will be counted as one. In this case, $y_2\ coordinate\ value > y_{ref}\ coordinate\ value$ can be said to cross the reference line.

F. Data Annotation

The need for efficient image recognition is crucial to be used in various application, such as for vehicle detection. In the literature, deep convolutional neural network models have shown remarkable achievement on many computer recognition tasks. However, these models are heavily reliant on big dataset of images taken to form a variety of conditions, such as different orientation, location, scale, illumination, etc. Unfortunately, many existing deep learning models were trained in a limited set of image conditions, which can increase problems of overfitting and hinder generalization performance. For instance, a poorly trained deep learning network would give high vehicle detection on the daytime condition but provide a poor performance on the night time. Thus, different types of illumination conditions would affect the model's performance in detecting vehicle objects. This results to lower accuracy obtained for vehicle counting systems.

Inspired by the work of [13], the data annotation tool is used to increase the variability of training images for generalization performance detection models. This tool consists of three main steps, namely, (a) main process - used to draw the bounding box, i.e. top-left and bottom-right points on image objects for yolo training; (b) convert - to transform the bounding box points into yolo input scheme, i.e. class id, x, y, width height of the image objects, whereby x and y is the centre point of the bounding box; (c) the process - used to split the train and test dataset for yolo training. In this work, about 510 new image objects from the video samples are used. The breakdown of total annotated vehicle images are as follows: bicycle (0), car (1866), motorcycle (457), bus (53) and truck (74).

IV. Experimental Results and Analysis

Our experiments contain two stages. In the first stage, we compare the proposed object detection algorithms, namely Faster R-CNN, SSD and Yolov3 on a set of videos. Based on the results of the first stage, we further extend the experiments by applying data augmentation using a data annotation tool to improve the detection performance. All the pre-trained models are trained on the COCO dataset and available on the TensorFlow detection model zoo (2019) and TensorNets [28]. The counting process takes some time, and it depends on the number of image frames and system configuration. We have performed experiments on Intel i5-8250 CPU @ 1.60GHz with 8GB memory and GeForce MX150 GPU with 6GB memory. In this work, vehicle accuracy counting is used to evaluate the performance of each detection model. It is determined by counting vehicles with ROI passing the reference line in image frames. The vehicle counting accuracy (VCA) is computed in equation (1) as follows:

$$VCA(\%) = \frac{Number\ of\ Detected\ Vehicles}{Total\ Number\ of\ Vehicles} \times 100 \quad (1)$$

A. Dataset

In this work, 10 sample traffic video clips from the same location in two different times of the day (day and night) are used in the experiments. The video was recorded in Kuala Lumpur, Malaysia from 06 a.m to 09 p.m under clear-sky condition. Fig. 5 shows some examples of day and night images with different traffic volume and day-night illumination variations. Table I shows the video list recorded from a CCTV camera and time information used in the experiments. Only vehicles flow in one direction is considered for counting. These videos are then converted to frames and each frame becomes the input to object detection algorithm while, the output are bounding boxes with coordinate and object label. After that, three detector models are used for comparison to be selected as the best vehicle detector for the counting system. These model are chosen based on the popularity in both past studies and availability of pre-trained models. Besides, they are widely used in industries for ease of implementation, especially on TensorFlow framework. These models are (a) Faster R-CNN (b) SSD and (c) YOLOv3. The first experiment (Experiment 1) investigates the best deep detector models for vehicle counting system in the day and night conditions for benchmarking. The second experiment (Experiment II) looks at improving the best method in the first experiment on selected conditions of traffic flow.

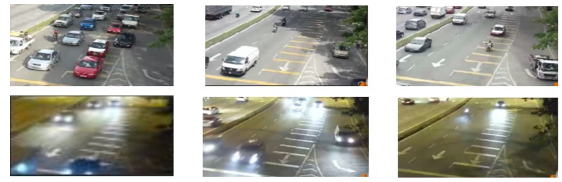

Fig. 5. Some Image Examples under Clear-Sky Condition in Kuala Lumpur, Malaysia. Top Half shows the Day Condition and Bottom Half shows the Night Condition.

TABLE I. Detail of Video Files used in Experiment 1. The Videos are Taken from 06 a.m to 09 p.m. The Value in Bracket shows the Ground-Truth Number of Vehicles for Each Session.

Video Files with time			
Video File	Time (a.m/p.m)	Video File	Time (a.m/p.m)
Video 1	06 a.m (140)	Video 6	01 p.m (266)
Video 2	08 a.m (453)	Video 7	02 p.m (322)
Video 3	10 a.m (262)	Video 8	04 p.m (358)
Video 4	11 a.m (280)	Video 9	07 p.m (237)
Video 5	12 p.m (299)	Video 10	09 p.m (202)

B. Experiment I

The best model in Experiment I is YOLOv3 and a detailed result is presented in the next section. Experiment I resulted in YOLOv3 as the architecture with the highest average counting accuracy for 10 sample videos tested, as shown in Table II. However, it was found that the performance of this model was worse in poor illumination, especially in the morning and night conditions. The YOLOv3 scores average vehicle counting accuracy of 66.29% compared to Faster R-CNN, which obtains the second-best average accuracy of 38.12%. On the other hand, SSD recorded the fastest processing time of 0.135 seconds per frame but has the lowest accuracy of 14.53%. The high standard deviation of the YOLOv3 and other models is due to the high variation of illumination change, especially in the morning and night conditions. As shown in Table III, YOLOv3 achieves very high accuracy during the daytime (10 a.m. to 2 p.m.) but in the early morning (6 a.m.), and night (9 p.m.) the accuracy is very low which is similar to other models. The overfitting of the pre-trained models can be seen appearing in all models tested here. Fig. 6 shows some detection results using different detection models, i.e. SSD, Faster R-CNN and Yolo V3. The accuracy vehicle counting comparison between all three models on two different time conditions (day and night) is shown in Table III.

Fig. 6. Some Detection Results in Experiment I using Different Models i.e. SSD, Faster R-CNN and YoloV3, respectively.

TABLE II. AVERAGE COUNTING ACCURACY AND PROCESSING TIME FOR EACH MODEL

Model	Counting Accuracy (%)	Processing Time (frame per second)
YOLOv3 DarkNetv19	66.29±33.35	0.26 ±0.013
FasterRCNN ResNet101	38.12±26.26	0.532±0.037
SSD Inception	14.53±14.40	0.135±0.004

C. Experiment II

The best performing model in experiment I is selected for further evaluation in Experiment II. The previous results have shown that the pre-trained models have some problems with a high variation of illumination in morning and night conditions. Thus, to overcome the problem, the data annotation technique is proposed. After that we compare the performance of the retrained model with the pre-trained model using the suggested data annotation tool. The retraining is done using a custom dataset taken from the video files. Firstly, the video files of type AVI are converted to a series of image frames of JPG type. Using the YOLO Annotation Tool [13], which is a Python executable program, the images of the vehicles are annotated and labelled. Bounding boxes are drawn on images of vehicles on video frames and labelled accordingly. To simulate the real traffic flow, two video clips were used one which is taken in the early morning (06 a.m.) and another at night (09 p.m.). In this work, about 510 images from poorly illuminated video samples were used. Breakdown of total annotated vehicles is bicycle (0 image sample), car (1866 image samples), motorcycle (457 image samples), bus (53 image samples) and truck (74 image samples). In this software, three additional files are required to perform the retraining. The files are (a) obj.names - contains the classes that need to be trained (b) obj.data - the pointers towards the location of the annotation files and images and (c)

TABLE III. THE OVERALL ACCURACY VEHICLE COUNTING ACCURACY FOR ALL DETECTOR MODELS.

Video time	YOLOv3 DarkNet19 (%)	Faster RCNN ResNet101 (%)	SSD Inception v2 (%)
06 a.m	2.86	0.71	0.00
08 a.m	73.73	23.18	11.26
10 a.m	94.27	61.45	17.94
11 a.m	83.93	52.14	8.58
12 p.m	96.32	28.76	10.37
01 p.m	89.84	30.08	12.78
02 p.m	86.65	82.30	40.68
04 p.m	74.02	70.95	41.62
07 p.m	57.82	29.11	2.11
09 p.m	3.47	2.47	0.00

Fig. 7. Some Detection Results using YOLOv3 DarkNet Detector Model (a) Top Half shows Detected Vehicle before Retraining (b) Bottom Half shows Detected Vehicle after Retraining using a Data Annotation Tool.

TABLE IV. THE AVERAGE DETECTION ACCURACY BEFORE AND AFTER DATA ANNOTATION

Detection Model	Before annotation (%)	After annotation (%)
YOLOv3 DarkNet19	66.29 ± 33.35	80.90 ± 11.62

tiny-yolo.cfg - is the model configuration file. The retraining process can be executed by using the training command to YOLOv3 DarkNet framework in the YOLO data annotation tool. The output of this process will be weight files for each 100th iteration.

The final weight file that is produced when the average loss ratio has saturated will be used for Experiment II. Then, results from this retrained YOLOv3 model is compared with the result in Experiment I that corresponding to the same video clip samples. The experiment shows that the counting accuracy has improved very significantly with counting accuracy from 2.86% to 75.71% and 3.47% to 76.73% in the morning (06 a.m) and night (09 p.m) conditions respectively. This is due to the model's ability to detect more vehicles in poor illumination conditions. Fig. 7 shows the average counting accuracy results of YOLOv3 before and after retraining using a data annotation for vehicle counting system. The counting system improves very significantly with average accuracy from 66.29% to 80.90%. Table IV shows the average detection accuracy on the standard Yolo V3 and the proposed data augmentation on Yolo V3.

V. CONCLUSION AND FUTURE WORK

This paper addresses the challenges in the selection of the best model for the development of a vehicle counting system for a custom dataset. Comparison of three models (Faster R-CNN ResNet101, SSD Inception, YOLOv3 Dark-Net) which were pre-trained on the COCO dataset showed that YOLOv3 DarkNet19 is achieving the best result. The results presented can be used as a reference for future development of a similar counting system. However, YOLOv3 DarkNet19 performs worse in the morning and night condition of the custom dataset. Thus, the solution is to retrain the model with a custom dataset from the poor illumination condition environment using a data annotation tool and employs transfer learning with the weight training initialization method. The resulting model improves the counting accuracy very significantly. A tracking mechanism based on consecutive frames comparison was also proposed to aid the counting system. This mechanism may work only on vehicles moving in one direction without occlusion. In future studies, perhaps some uniformity can be done on the meta -architectures and detectors. Besides, the model used for retraining was a light-weighted version of YOLO, which is called tiny-YOLO. This is due to the limitation on the available hardware specification. To retrain YOLO the recommended minimum GPU memory is 4GB, any specification below that is only suitable for training tiny-YOLO. Thus, it is recommended that future studies need to consider the retraining of YOLO instead of tiny-YOLO to compare the performances.

Acknowledgment

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Predicting Customer Retention using XGBoost and Balancing Methods

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***Abstract*—Customer retention is considered as one of the important concerns for many companies and financial institutions like banks, telecommunication service providers, investment services, insurance and retail sectors. Recent marketing indicators and metrics show that attracting and gaining new customers or subscribers is much more expensive and difficult than retaining existing ones. Therefore, losing a customer or a subscriber will negatively impact the growth and the profitability if the company. In this work, we propose a customer retention model based on one of the most powerful machine learning classifiers which is XGBoost. The latter classifier is experimented when combined wit different oversampling methods to improve its performance in the used imbalanced dataset. The experimental results show very promising results compared to other well-known classifiers.**

***Keywords*—Customer retention; churn prediction; oversampling; XGBoost**

I. Introduction

The sector of telecommunications has grown into a principal industry in the developed countries [1]. Technical progress, in addition to the growing number of operators, increased the degree of competition in this sector. The firms are, thus, working hard so as to survive in this highly-competitive market and are using varying strategies for this purpose. In this respect, three major strategies have been suggested for generation of further revenues [2], [1]: (i) gaining new customers, (ii) increasing the sales to the present customers, and (3) increasing the period of retention of the customers. A comparison of effectiveness of these strategies based on the Return on Investment (RoI) achieved from each revealed that the last strategy is the most rewarding strategy [1]. This suggests that retaining a current customer costs the firm much less money than gaining a new one. Moreover, retention is much easier than increasing the sales to the current customers [1]. For successful application of the third strategy, the firms need to reduce the potential for churn of the customers.

Customer churn can be defined as a customer who terminates their relationship with the service provider and switches to another competitor in the market [3]. In the dynamic market, there are different types of factors that influence the decision of customer when he/she decides to churn. These factors include: Technological factors where a customer will be motivated to switch to a competitive company which offers more technological advanced products. Economic factors, for example, cheaper price or product offered by a competitor. Quality, as poor quality of customer service will push him to leave his company like the Weak coverage. Or even the difficulties in the usage of a product and delays in delivering a service or product [4].

Nowadays, telecom service providers pay a great attention for customer retention than customer acquisition because the cost of getting a new customer is more than the cost of keeping an existing one. Consequently, well-known telecom companies consider that their current customer database is the most beneficial asset [3].

Customer churn prediction is a concept of predicting and identifying those customers who are about to churn by leaving the telecom company to another competitors [5], [3]. Churn prediction models assistance in effective customer churn management. Predicting churn assists the preparation of targeted preservation strategies to limit the losses and to enhance marketing decisions build customer loyalty and increasing profitability [6]. For example, specific incentives and offers can be given to the most risky customer segments. Marketing department, can plan awarding customers discounts, other promotions/events, other products of other sister companies wherever applicable [7].

Churn management is defines as a concept that investigates operator's process which save profitable customers [7]. Whenever a given company attempts to determine customers whom want to churn before they do that is considered as proactive churn management approach. After that company gives special offers (promotions) for such customers to prevent their churning. Those considered offer programs gain very important advantages of getting lower cost. On the other hand, if churn predictions of such approaches are inaccurate, they will be considered as wasteful since companies will waste money for customers whom will not churn. Consequently, to get a major success of customer incentive programs, there is a crucial need to have an accurate customer-churn prediction model [7], [8].

In the last two decades, several machine learning algorithms were proposed in literature to tackle the churning prediction problem. The first type of these algorithms is the basic machine learning algorithms and the most popular ones. Such algorithms include Artificial Neural Networks, Decision Trees learning, and Logistic Regression, Support Vector Machines (SVM), Naïve Bayes and many others [9], [3], [5].

Another type of machine learning models for churn prediction is the ensemble algorithms which are based on the concept of ensemble learning. Ensemble learning is a way of developing various weak classifiers from which a new classifier is derived which performs better than any of the weak classifiers [3]. These weak classifiers may differ in the algorithm used, hyperparameters, the training samples or the included features. Examples of Ensembles of churn prediction include Random forest, RotBoost, Rotation Forest [10], [5], [11].

One of the major problems with churn prediction is the imbalanced distribution of the classes as the number of non-churning customers are much more than the churning ones [12], [1], [3]. This makes it challenging for the machine learning classifiers to discover the churning customers. Different approaches were proposed for handling this issue for churn prediction such as over-sampling and under-sampling [3], [11], [13].

In this work, we propose and experiment the application of one the most powerful and effective classification algorithms in the last few years which is Extreme Gradient Boosting (XGBoost) for churn prediction in telecommunication business. The performance of XGBoost is experimented after combining it with different popular oversamling methods to improve its performance when applied for imbalanced dataset. This application is introduced by a technical framework and that explains the application in details. The performance is measured using different evaluation metrics and compared with common and well-known classifiers.

This paper is structured as follows: In Section II we review and discus the previous imbalanced distribution data studies, whereas in Section III we review the main methods that will be used in the proposed framework. In Section IV we describe the framework of XGBoost combined with oversampling methods. In Section V, the dataset used in this work is described. The evaluation measures are listed in Section VI. The experiments and results are described and discussed in details in Section VII. Finally the conclusion of this work is given in Section VIII.

II. Related Works

Many researchers have looked at the imbalanced data problem where the numbers of the classes of the churned customers are lower than those of the classes of active customers, which is quite a serious issue in the churn prediction [3].

Idris et al [11] suggested an approach that is based on genetic programming using AdaBoost so as to model churn problem in the telecommunications sector. These researchers employed a Particle Swarm Optimization-based under-sampling in order to tackle the imbalance in the telecom data. This method provides an unbiased distribution of the training set to a prediction system that is depending on GP-AdaBoost. Performance of this proposed approach was evaluated on two standard datasets, one for Orange Telecom and one for cell2cell. The generated churn prediction accuracies were 0.86 AUC for the Orange Telecom data and 0.91 AUC for the cell2cell data.

Faris [3] presented hybrid model that is based on the over-sampling method, which integrates Particle Swarm Optimization (PSO) with a Random Weight Network for solving the problem of churn in the telecommunications data. The researchers applied the ADASYN over-sampling method in order to enhance learning from the imbalanced churn data. The results showed that use of the ADASYN method could significantly enhance the rate of coverage of the churn customers. Furthermore, this hybrid model is characterized by high interpretability since the allotted feature weights provide indicator of importance of their respective features in the process of classification.

Hanif and Azhar [14] employed the data-balancing methods of Synthetic Minority Over-sampling (SMOTE), random under-sampling, and random over-sampling in their efforts to tackle the problem of class imbalance. They found that random over-sampling generated the best data-balancing results. Hence, these researchers concluded that the extracted features that are most important are actually the features related to the customer's call. Amin et al. [13] held comparison in levels of performance of six over-sampling methods, namely, the SMOT, Mega-Trend Diffusion Function (MTDF), coupled top-N reverse k-nearest neighbor, adaptive synthetic sampling, immune centroid over-sampling, and majority weighted minority over-sampling methods. Their empirical findings indicated that the net predictive performance of the MTDF and the rules generation based on genetic algorithms methods were better than the levels of performance of the other assessed over-sampling approaches and the rule-generation algorithms.

Faris [15] applied the Neighborhood Cleaning Rules (NCL) under-sampling method for balancing churn data. The NCL method takes quality of the removed data into consideration by conducting data cleaning rather than data reduction. After application of the NCL method, a modfied version of the PSO, commonly known as the Constricted PSO, is trained so as to develop the churn prediction model. Tests showed that the NCL could signficantly improve the rate of coverage of the churn classes.

Idris et al [16] suggested intelligent churn prediction system for the telecommunication data by using efficient feature extraction method and an ensemble method. They employed under-sampling in order to handle the data imbalance problem and found that the minimal redundancy and maximal relevance (mRMR) technique could return the most explanatory features when compared with the Fisher's ratio and the F-score. Moreover, the RotBoost method combined with the mRMR features provided appreciably high prediction performance when applied on the standard telecommunication datasets.

Idris et al. [10] employed PSO-based under-sampling for the purpose of churn prediction. The function of the PSO is to search for the examples that are most informative of the majority class, order them, and integrate them with the minority class so as to maximize the classification accuracy. These researchers chose maximizing AUC as the fitness function in conjunction with the Random Forest (RF) and the k-NN classifiers. The evaluation results uncovered that the PSO-based technique enhanced performance of the k-NN and the RF classifiers.

Qureshi et al. [17] presented discussion of use of under-sampling and over-sampling approaches for solving the class imbalance problem to identify the customers who are close to churn on the basis of historical data. Burez and Van den Poel [8] researched into the data imbalance problem in the models for churn prediction and compared the levels of performance between Advanced Under-Sampling, Random Sampling, Weighted Random Forests, and the Gradient Boosting Model. They employed the AUC and Lift as the model performance metrics. The evaluation outcomes revealed that the under-sampling technique outpaced the other examined methods.

In order to tackle the churning prediction problem for the telecommunication companies, an approach based on the XGBoost classifier with over-sampling methods is proposed. Four common and renowned over-sampling methods are used and a comparison is held between them in terms of their abilities to handle the data imbalance problem, which are random over-sampling, SMOTE, ADASYN, and Borderline SMOTE.

III. Methods

This section describes the oversampling methods and the XGBoost which are applied to build the retention prediction model in this work.

A. Oversampling Methods

In this section the used oversampling methods for churn prediction will be described.

1) Random Oversampler: One possible method to tackle the oversampling problem is to create new samples in the classes which are under-represented. The most easy and basic approach is to generate new rare samples by randomly sampling with replacement the current available rare samples which is simply copying some of them.

2) SMOTE: [18] is concerned with creating new synthetic data points that are very similar to the real data points. Given a dataset D with N number of data instances. Where a^M is the number of instances of the major class M and b^m is the number of instances of the minor class m. Mainly, SMOTE focuses on increasing the ratio of the minor class by synthesizing new data points. It starts by selecting a minority-labeled data point i with a number of nearest neighbors k. In which, the selected neighbors are from the minor class. Depending on a predefined sampling rate, a random number of the points of the selected neighbors are chosen. Hence, those randomly-selected neighbor points create a line segment that links them with the data point i. From each line segment, a random point is selected to be the new synthetic data point. This process is repeated for all minority-labeled data points.

3) ADASYN: In 2008, Another over-sampling strategy was designed, which is ADASYN [19]. ADASYN was suggested to alleviate the bias during the learning process and to perform adaptive learning by adaptively setting the decision area of the minority points that are difficult to learn. In ADASYN, the ratio of the minority instances to the majority instances d is calculated to find the appropriate number of synthetic instances G for the minority class (Eq. 1).

$$G = (b^m - a^M) \times \beta, \qquad \beta \in [0,1] \tag{1}$$

For each minority-labeled point, a k number of nearest neighbors is determined. The ratio of the majority class of the neighbor set is computed by $r_i = No.majority\ points/k$. Whereas, the normalization of r_i represents the density distribution ($r_i^{'}$). The adoption of a density distribution makes ADASYN different than the previous algorithms to adaptively learn the data points of the minority class. The density distribution is used to find the number of synthetic points for each minority data point, as in Eq. 2.

$$g_i = r_i^{'} \times G \tag{2}$$

For each minority data point x_i, one random point of the minority-labeled points of the neighbor set x_j is selected to generate the synthetic points g_i. The new data points are created as in Eq. 3. In which, $diff_j$ is the difference between x_i and x_j, and λ is a random number.

$$x_{new} = x_i + diff_j \times \lambda, \qquad \lambda \in [0,1] \tag{3}$$

The density distribution of ADASYN defines non-uniform weights of the minority points, which lead to effectively decide the number of synthetic points to be generated for each minority-labeled point.

4) Borderline SMOTE: In 2005, Borderline-SMOTE was proposed [20], which is an extension of SMOTE with more powerful performance ability. Essentially, Borderline-SMOTE performs two stages; classifies the neighbors into three types of regions to identify the borderline instances, then synthesizes the new points. In the first version of Borderline-SMOTE (Borderline-SMOTE1), the new data is solely created from the determined borderline instances.

In Borderline-SMOTE1, the nearest neighbors of a minority data point are selected regardless of the type of the class (major or minor). Thus, the rate of the points of the major class of the selected neighbors decides whether the corresponding data point belongs to the noise, danger, or safe regions. If the neighbors of the minority point are all form the majority class, then it is classified as a noise point. If the neighbors contain majority points of ratio greater than $b^m/2$, then the respective data point is classified as a danger point. While having the number of majority-labeled points with a ratio of less than $b^m/2$, results in classifying the respective point as a safe point. As a result, all minority points classified as danger points called borderline instances. In order to create new points, for each point from the danger region p_i, a k number of neighbors is selected from the same minority class. Hence, a randomly s points are chosen from the neighbors. The difference is calculated between each point from s and the respective danger point, where the difference denoted by ($diff_j$). Then the new synthetic data point is generated based on Eq. 4, given that r_j is a random number $\in [1, s]$.

$$p\_new = p_i + r_j \times diff_j \tag{4}$$

In version 2 of the Borderline-SMOTE, the neighbors of the points at the danger region are considered from the two classes; the minority and the majority.

B. XGBoost

Extreme Gradient Boosting (XGBoost) can be defined as an improved version of the Gradient boosting algorithm, and this algorithm considers one of the machine learning techniques\tools that applied for classification and regression problems. The idea behind its concept is to boost the weak learner to become stronger using the decision trees mechanism. This improved version utilized a more regularized model in order to reduce and control the overfitting of the model to improve its performance. Basically, the XGBoost adopted the three main techniques of the gradient boosting, which are Regularized, Gradient and Stochastic boosting to enhance and tune the model. Moreover, it has the ability to decrease the time consumption alongside using the optimal resources of memory, parallel execution and handling the missing values while generating the tree construction [21], [22].

The XGBoost as the tree algorithms implementation considers the features in the dataset as a conditional node, where it divides into various branches and splits until the leaf node that represents the selected detection of the problem. In addition, the XGBoost depends on its hyperparameter in order to perform well considering its number and characteristics.

IV. XGBoost with Oversampling

In this section, the framework for customer churn prediction is described, see Fig. 1. The main two components of this framework are the classification algorithm and the oversampling method. For classification, the powerful XGBoost classifier is used. While for oversampling, we try four different oversampling methods all of them are variations of the SMOTE algorithm which are the basic version of SMOTE, ADASYN, SMOTE borderline, and the simplest method which is random oversampling. The proposed framework have the following steps:

- First, the dataset will be split into two parts. The first part is used for parameter tuning, while the second part will be used for training and testing the developed models. A stratified sampling is used because the dataset is imblalanced and it important to have the same ration of class labels in both samples of parts.
- In the second step, the parameters of XGBoost are tuned using the GridSearch algorithm implemented in Python. This is very important step because XGBoost is vert sensitive to the initial values of its many parameters. This step will assure to maximize the performance of the classifier in the rest of the experiments.
- The second part of the dataset is used to trian and test the algorithm using the 10-folds cross validation technique. Using this way, 9 folds are used to train the model and one fold is used for testing the model. This process is repeated 10 times. Then the average of the results are calculated.
- The next step is the oversampling method. In this step four very popular oversampling methods are used: Random oversampler, SMOTE, ADASYN and Borderline SMOTE. It is very important to note that these oversampling methods are applied only in the training folds. All the oversampling methods are applied at different oevrsampling ratios to study the effect of this ratio on the classification results of the classifier.
- After the oversampling step, the XGBoost is trained using the oversampled data and tested on the testing data which is not oversampled.
- After applying the cross validation process, the performance of the XGBoost is evaluated using the common classification metrics which are : the accuracy rate, precision, recall, and F1-measure.

V. Description of Churn Dataset

The dataset used in this work which is used to build the retention prediction models consists of information of 5000 subscribers and includes independent 20 variables which are shown in Table I. Note that three features were removed from the dataset because they do not provide any information which are: state, area code, and phone number. The dependent variable in the dataset is whether the customer left the company or not, which is coded as 1 for “yes” and 0 for “no.”. In the dataset there 707 customers who left the company so the ratio of churn in the dataset is 14%.

TABLE I. List of Features of the Churn Dataset.

State	Total eve minutes
Account length	Total eve calls
Area code	Total eve charge
Phone number	Total night minutes
International plan	Total night calls
Voice mail plan	Total night charge
Number vmail messages	Total intl minutes
Total day minutes	Total intl calls
Total day calls	Total intl charge
Total day charge	Number customer service calls

VI. Evaluation Measures

In this paper, the precision, recall, accuracy and F-measure performance criteria are used to evaluate the XGBoost and the selected, well-known benchmark classifiers in churn prediction for the telecommunication sector. The four performance evaluation criteria are computed based on the confusion matrix presented in Table I. The false positive and true positive cases are denoted as FP and TP, respectively, while the false negative and true negative cases are abbreviated as FN and TN, respectively [9] (Table II).

On the other hand, the precision is the percentage of correctly-predicted positive cases. It is computed using the following equation [9]:

$$Precision = \frac{TP}{TP + FP} \tag{5}$$

TABLE II. Confusion Matrix

		Predicted Class	
		Non-churners	Churners
Actual Class	Non-churners	TN	FP
	Churners	FN	TP

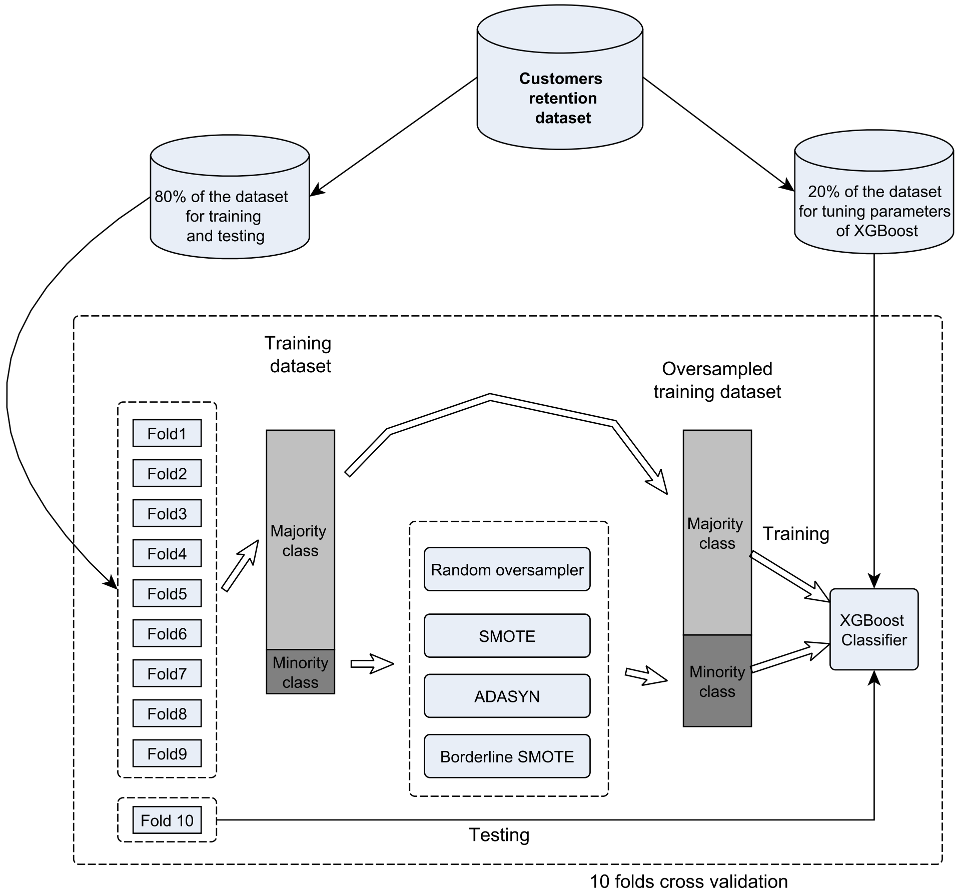

Fig. 1. Framework of XGBoost with Oversampling for Customer Churn Prediction.

In other respects, recall expresses the percentage of the correctly-predicted positive cases. It is calculated using the equation [9]:

$$Recall(Sensitivity) = \frac{TP}{TP + FN} \tag{6}$$

Meanwhile, the accuracy represents the percentage of the total correct predictions. It is given by the equation [9]:

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \tag{7}$$

Recall or precision alone can not describe efficiency of the classifier owing to that a good performance according to one of these two indices does not necessarily mean good performance according to the other. On account of this, the F-measure, which is common combination of these two metrics, is frequently employed as a single metric for evaluation of performance of the classifier. This measure is defined as the harmonic mean of recall and precision [9]:

$$F - measure = \frac{2 \times Precision \times Recall}{Precision + Recall} \tag{8}$$

The closer the F-measure to one, the better. An F-measure value that is close to one means that a good combined recall and precision is provided by the classifier under evaluation [9].

VII. Experiments and Results

In this experiment we used python3 and the following libraries : `Scikit-learn` is a library in Python that provides many unsupervised and supervised machine learning algorithms. This library is built based on other popular libraries like `NumPy`, `Pandas`, and `Matplotlib`. For the oversampling algorithms, the `Imbalanced-learn` is used. `Imbalanced-learn` imbalanced-learn is a Python package that provides a set of resampling algorithms commonly used for imbalanced datasets.

A. Experiments Setup

For parameter tuning of the machine learning classifiers, one fifth of the dataset which is 1000 instances are used for this task. To perform this task, the `GridSearchCV` from `sklearn` library in Python is used. `GridSearchCV` function is applied with 3 folds cross validation to find the best parameters of Random Forest, SVM, XGBoost, Logistic Regression and SGD classifier. The ranges of the parameters to be searched by the `GridSearchCV` are specified as given in Table III. The best parameters of this experiment are listed in Table IV.

The rest of the dataset which are 1000 instances (customers) are used for training and testing the machine learning classifiers using 10 folds cross-validation.

TABLE III. RANGES OF PARAMETERS FOR GRID SEARCH

Classifier	Range of Parameters
RandomForest	N_estimators: start:200,end:2000
	Max_features : ['auto', 'sqrt']
	Max_depth:start:10,end:110
	Min_samples_split : [2, 5]
SVM	C: [0.1, 1, 10, 100, 1000]
	Gamma: [1, 0.1, 0.01, 0.001, 0.0001]
XGboost	Min_child_weight :[1, 5, 10]
	Gamma: [0.5, 1, 1.5]
	Subsample: [0.6, 0.8, 1.0]
	Colsample_bytree: [0.6, 0.8, 1.0]
	Max_depth: [3, 4, 5]
LogisticRegression	C: [1e-7, 1e-6, 1e-5, 1e-4, 1e-3, 1e-2, 1e-1, 1e0]
SGDClassifier	Alpha: [1e-4, 1e-3, 1e-2, 1e-1, 1e0, 1e1, 1e2, 1e3]

TABLE IV. BEST PARAMETERS FOR MACHINE LEARNING CLASSIFIERS USING GRID SEARCH METHOD.

Classifier	Best parameters
Random Forest	Max_depth: 60
	Max_features: sqrt
	Min_samples_split: 2
	N_estimators: 1100
SVM	C: 0.1
	Gamma: 0.0001
	Kernel: rbf
XGboost	Colsample_bytree: 0.8
	Gamma: 1.5
	Max_depth: 5
	Min_child_weight: 1
	Subsample: 1.0
Logistic Regression	C: 1.0
	Penalty: l2
SGD	Alpha: 1.0
	Loss: log
	Penalty: l2

B. Comparison of XGBoost with Other Classifiers

In this experiment the XGBoost and the other machine learning classifiers are applied on the dataset to build customers retention models but without applying any balancing methods. The result of this experiment are given in Table V. From the result we can see that XGBoost and Random Forest performed much better than the other classifiers which are SVM, Logistic Regression, and SGDClassifier in all measures especially the F1 measure. On the other side there is small difference between the results of the XGBoost and Random Forest with the small advantage for XGBoost.

C. Comparison of XGBoost with Other Classifiers after using Weighting Method

In this experiment we study the effect of the class balancing method on the results of machine learning classifiers that were applied in the previous experiment. The results of this experiment are given in Table VI. We can see that performance of the SVM, Logistic Regression, and SGD classifier was improved. However that the performance of the XGBoost and Random Forest is still much more better than the performance of the other classifiers. On the other side the class balancing method has not improved the accuracy and F1 measure of Random Forest and XGBoost.

D. XGBoost Combined with Oversampling Methods

In this section, the performance of XGBoost combined with oversampling methods is experimented. The oversampling methods are: Random oversampler, SMOTE, ADASYN, and Borederline SMOTE. All of these oversampling are tested with XGBoost at different oversampling ratios starting from 20% until 100%.

Fig. 2 shows the results of Random oversampler combined with XGBoost. It can be seen that the recall increases by the increase of oversampling ratio until it reaches around 81% at oversampling ratio 100%. The best F1 measure was reached at 40%. This increase in F1 and recall decreased the ratio of precision from around 91% to around 84%.

Fig. 3 shows the results of SMOTE combined with XGBoost. It can be seen that the recall increases by the increase of oversampling ratio until it reaches around 78% at oversampling ratio 100%. The best F1 measure was reached at 20%. This increase in F1 and recall decreased the ratio of precision from around 93% to around 85%.

Fig. 4 shows the results of ADASYN combined with XGBoost. It can be seen that the recall is almost constant. The best F1 measure was reached at 40%. This increase in F1 and recall decreased the ratio of precision from around 91% to around 87%.

Fig. 5 shows the results of BorderLine combined with XGBoost. It can be seen that the recall increases by the increase of oversampling ratio until it reaches around 78% at oversampling ratio 100%. The best F1 measure was reached at 20%. This increase in F1 and recall decreased the ratio of precision from around 93% to around 86%.

VIII. CONCLUSIONS AND FUTURE WORKS

In this work, an approach based on Gradient Boosted Trees algorithm with oversampling methods is proposed for predicting customer retention in telecommunication companies. In this approach four common and well-regarded oversampling methods are used and compared which are: random oversampling, SMOTE, ADASYN, and Borderline SMOTE. The first part of the experiments showed that Gradient Boosted Trees without oversampling outperforms other popular classifies including SVM, Random Forests, Logestic Regression and SGD classifier. In the second part of the experiments, the oversampling methods were applied at different oversampling ratios. The experiments reveal that the oversampling methods improve the performance of Gradient Boosted Trees in predicting the churn class and the best F-measure value (which is around 84%) can be reached with SMOTE method at oversampling ratio of 20%.

TABLE V. Comparison of XGBoost with Other Classifiers.

	Accuracy	Precision	Recall	F1 measure
RandomForest	0.955 (0.008)	0.936 (0.044)	0.743 (0.053)	0.827 (0.033)
SVM	0.827 (0.021)	0.351 (0.065)	0.225 (0.056)	0.272 (0.058)
XGboost	0.956 (0.009)	0.924 (0.052)	0.752 (0.057)	0.829 (0.052)
LogisticRegression	0.864 (0.016)	0.618 (0.154)	0.204 (0.042)	0.302 (0.052)
SGD	0.801 (0.193)	0.552 (0.208)	0.225 (0.275)	0.223 (0.120)

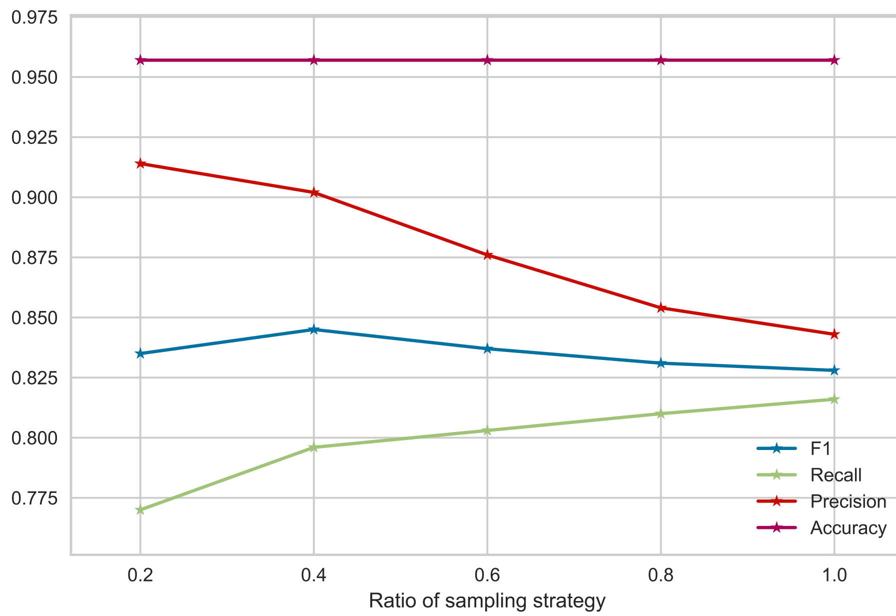

Fig. 2. Effect of Sampling Strategy Ratio of the Random Oversampler on Evaluation Measures of XGBoost.

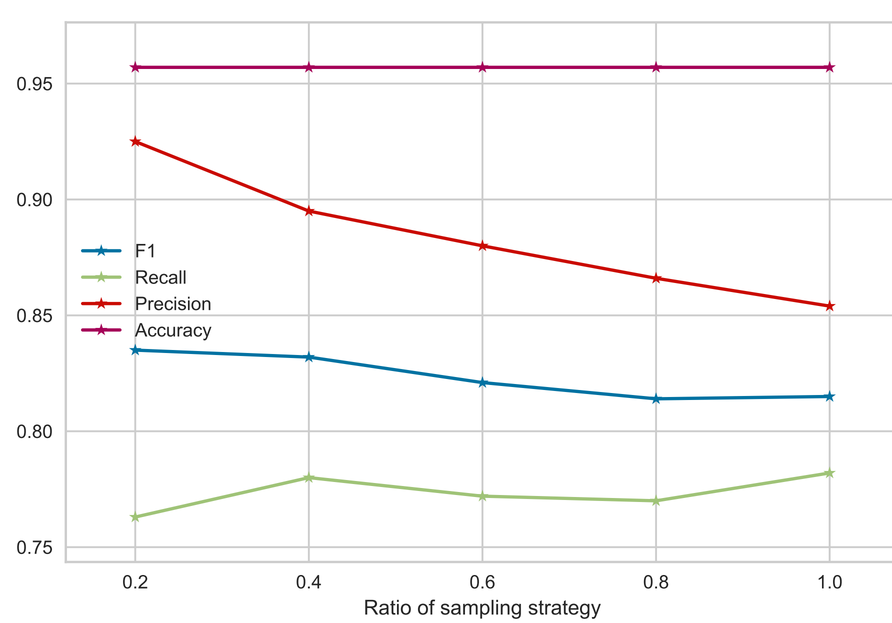

Fig. 3. Effect of Sampling Strategy Ratio of the SMOTE on Evaluation Measures of XGBoost.

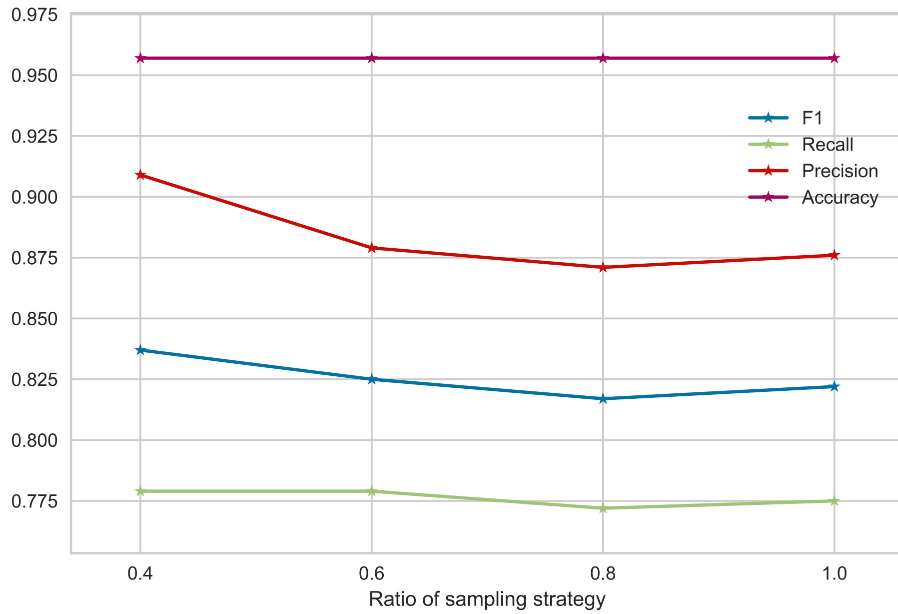

Fig. 4. Effect of Sampling Strategy Ratio of ADASYN on Evaluation Measures of XGBoost.

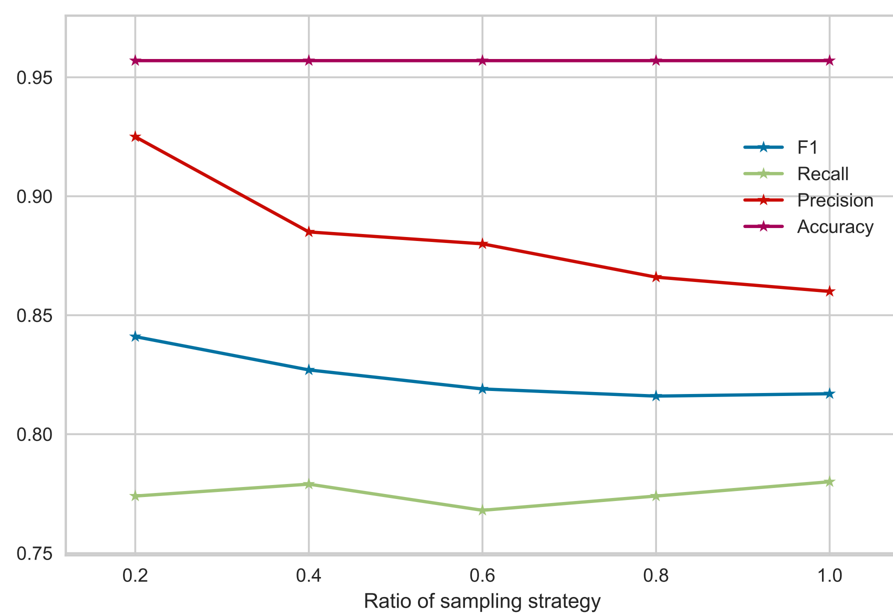

Fig. 5. Effect of Sampling Strategy Ratio of BorderLine SMOTE on Evaluation Measures of XGBoost.

TABLE VI. COMPARISON OF XGBOOST WITH OTHER CLASSIFIERS AFTER APPLYING CLASS WEIGHTING METHOD.

	Accuracy	**Precision**	**Recall**	**F1 measure**
Random Forest	0.955 (0.008)	0.902 (0.042)	0.770 (0.057)	0.830 (0.044)
SVM	0.768 (0.023)	0.286 (0.036)	0.398 (0.078)	0.330 (0.043)
XGboost	0.948 (0.009)	0.822 (0.059)	0.818 (0.048)	0.819 (0.045)
LogisticRegression	0.773 (0.014)	0.366 (0.048)	0.770 (0.037)	0.495 (0.048)
SGD	0.519 (0.247)	0.230 (0.120)	0.608 (0.294)	0.273 (0.050)

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Proposal for a Software Architecture as a Tool for the Fight Against Corruption in the Regional Governments of Peru

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***Abstract*—This paper covers the problem of corruption in Peru, with an emphasis on regional governments, and presents a proposal for an anti-corruption software application architecture for those levels of government. The design of the proposal starts from the analysis of corruption encompassing statistical studies, trust evolution, government management, legal situation and incidents in information technology. Also, aspects of the budget allocation, crime data, political party financing data, management resources, contracting processes, integration systems and citizen participation are presented, for the subsequent presentation of the data structure and resources for the software application architecture. The methodology used is of an exploratory documentary type. In addition, a systemic approach and development are considered in three layers: data persistence, logical process, and presentation; considering the interrelationships that must exist between them for the development of the proposed architecture.**

Keywords*—*Software architecture; anti-corruption; regional government; local government; corruption perception index

I. Introduction

Globally, corruption problems are a global concern because it is a multidimensional phenomenon that occurs systematically and at different levels and sectors of the countries [1]; which by misusing public or private power directly affects the development of countries, weakening governance, trust and rights of people. As defined universally and in the legal codes of Latin American nations, corruption is "the abuse of public power and the position for private benefit" [2].

Corruption materializes when there is a closed set of factors such as political, economic, cultural, social and axiological that influence the performance of officials, who easily fall for acts of corruption, such misuse of public funds mainly limits the effectiveness of social policies, strongly impacts the most vulnerable populations and allows the participation of illegal activities in the sphere of decision-making [3].

According to Transparency International, in the Corruption Perception Index (CPI) 2019, more than two thirds of the countries obtain scores lower than 50, with an average score of only 43. Denmark occupies the first place with the lowest corruption index worldwide. At the other extreme, the country with the highest perception of corruption is Somalia, the most corrupt since 6 years ago [4]. In the case of Peru, it registers a PCI equal to 35 out of 100, which places it in the world ranking in 101st place out of 180 countries, although Peru is above Brazil, Bolivia, Paraguay and Venezuela. However, it is still below the Latin American average as shown in Fig. 1.

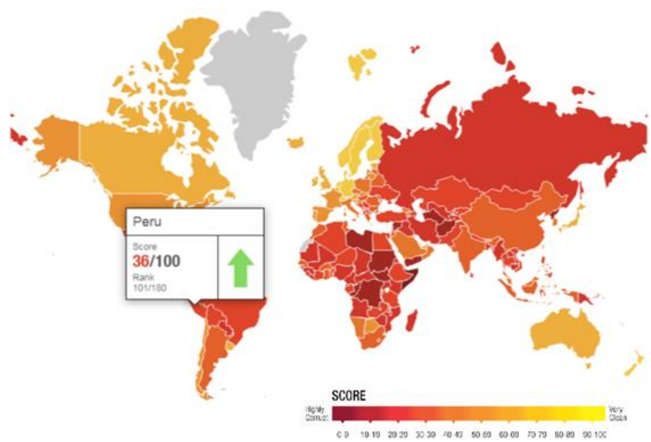

Fig. 1. Heat Map on the Corruption Perception Index 2019.

Although it is true, worldwide and predominantly Latin American, corruption problems are really worrying, however, in recent years, some countries have taken measures to mitigate this global problem. Organizational processes can be ISO 37000 anti-bribery certification based that consists of demonstrating the integrity of an organization and mitigating exposure to the risks of bribery [5].

According to Proética, a Peruvian chapter of Transparency International, 62% of the Peruvian population identifies corruption as one of the main problems in the country and 73% of the citizens consider that corruption will continue to increase in the next five years [6]. Perhaps motivated by impunity, the bad example of authorities of the highest rank and the perception that there are no effective sanctions; This triggers a general feeling in the population of high exposure to it, resignation, lack of mechanisms to eradicate it and therefore a great barrier to implement real and effective mechanisms to fight corruption.

In this context, information and communication technologies, data analytics and big data tools allow us to have the ability to predict, to emulate a reality and anticipate changes in the environment, using quantitative and qualitative methods to process the data and information available, in order to solve problems and predict relevant results in the fight against corruption [7, 8, 9, 10, 11, 12, 13, 14]. Consequently, [15] discusses three questions aimed at public policy decision-makers on the use of data, data science and new technologies to fight corruption: a) what data is important to prevent and Investigate acts of corruption? b) If they exist, how can data science be used to process them? and c) if a national or local government wants to adopt these alternatives, what actions should it take? Finally, policy recommendations are mentioned to governments in the region to make data-driven anti-corruption initiatives and new technologies more effective.

Coding of the information system software requires determining the software architecture as a consequence of an analysis of the functionalities and processes of the governmental institutions of the regions of Peru, and the proposal of new processes and interrelations. Thus, this research covers the software architecture design that considers various regional government organizations, citizen participation and the use of information technologies related in an integrated way to achieve strengthening transparency in the management of regional governments and reducing corruption in those regions.

Therefore, this paper has the following structure: global context of IT as anticorruption tool, analysis of corruption in regional governments in Peru, resources and data for the anti-corruption application architecture and proposal of the data structure and resources of the application architecture, additionally to results, conclusions and future work.

II. Current Context of the use of IT in the Fight Against Corruption in the World

In recent years, various countries have been incorporating ICT in government procurement processes, as well as mechanisms for public transparency of information. In this sense, a leading country is Estonia; who makes use of high technology and a transparent and available digital registration system, making it one of the least corrupt countries in the world [16].

There are some computer platforms developed to reduce corruption, such as GoAML (detection platform for money laundering networks) and GoINTEL (financial intelligence information exchange platform) developed by The United Nations (UN) [17]. Furthermore, in the European Union, Ukraine has an online procurement platform called ProZorro by simplifying oversight opportunities for the civil society and by enabling enhanced, open competition among businesses that aim to supply goods and services to the government entities. Likewise, The DoZorro artificial intelligence application was developed by Transparency International (Ukraine Chapter) in addition to the risk identifiers generated by the State Audit Service of Ukraine and serves to capture information from the electronic contracting national system ProZorro, to determine possible faults in the law or anomalies in the contracting processes and to identify tenders with a high risk of corruption [18]. Also, an early warning system for corruption in Spain based on neural networks was developed. This analyzes various data, such as property taxes, unemployment rate and number of years in government, etc.; and consequently it could predict corruption in the public sector and uncover hidden indicators of legal and economic problems including money laundering in the European Union [19].

In Latin America, an anti-corruption software, named IAC, was developed by The Comptroller of the province of La Guajira (Colombia) to measure the level of corruption in the institutions of the region, considering items such as accountability, customer service, among others. It could help the departmental administration, municipalities, educational institutions and all entities and that administer public resources to evaluate the country's management [20]. Also, the corruption risk algorithm was developed in Peru by the organization Ojo Público, named FUNES. This seeks links with companies to determine the possibility of winning in public procurement, managing to extract information from public databases on contracts made by the Peruvian government to investigate possible corruption risk scenarios and identify political and financial connections [21].

In some countries, mobile applications have been used mainly to instantly report corrupt acts. The “Action for Transparency (A4T)” app was launched by Transparency International in Uganda and Kenya that fights corruption and mismanagement of government funds. The citizen can to check the amount of government money pledged to each school and health clinic – and the amount actually spent [22]. Next, the “Bribr” app was launched by an entrepreneur in Russia, it allows the citizens to anonymously register and categorize bribes and show corruption problems [23]. Also, the "Transparencia al Instante" app was launched by the Transparency Unit of the City Hall of La Paz (Bolivia) to report acts of corruption or irregularities of the municipal public officials [24], and “Obras Transparentes” app launched by Ministry of Public Works, Services and Housing of Bolivia [25]. Also, the "Dilo Aquí Guate" app was launched in Guatemala by the Tigo Foundation and the NGO Acción Ciudadana. This allows confidential reporting of fraud, illicit enrichment, bribery, abuse of authority [26]. Furthermore, the "Denuncia la Corrupción Querétaro" app was launched in the city of Querétaro (Mexico), in order for citizens to participate in the mitigation of corruption. It includes a track mechanism for the complaint made [27]. Also, the “Elefantes Blancos” app launched by the government of Colombia. It seeks identify and track information about public construction works that have been neglected, abandoned or overbilled [28].

Particularly, in Peru has been implementing the National Policy for Integrity and the Fight against Corruption and other initiatives at the level of web-based technology platforms [29], although there is minimal use of information and communication technologies to mitigate this problem [30].

III. Analysis of Corruption in Regional Governments in Peru

Peru is governed by being a unitary and decentralized government; unitary, because it is a single entity with common duties and shared goals aimed at the general welfare or protection of citizens. It is also decentralized because Peruvian governance must be exercised at three levels of government: national government (also known as the central government), regional government, and local government (provincial and district municipalities). Decentralization, to that extent, is a democratic process and a permanent compulsory government policy whose objective is the integral development of the country [31]. However, part of the corruption problem has been increased and focused on regional governments (twenty five regions), this level of government that began its implementation since 2002 [32], in order to promote participatory decentralization in Peru, brought with it some positive aspects such as generating better development and quality of life for the inhabitants of its regions; however, due to the lack of policies, strategies and the due commitment of its officials, in several of the regions the different cases of corruption began to be identified [33, 34, 35].

According to the National Institute of Statistics and Informatics (INEI) of Peru, inquests in 2019, carried out on the perception of acts of corruption in Peruvian households by region [36], it was obtained that 4.2% of the households consulted reported that some member of their household was asked for an “extra payment” when making arrangements or requesting services in Public Institutions. Madre de Dios and the Lima region reported the highest percentages in "extra payments" of 8.8% and 7.9% respectively, while in Ayacucho 0.2% of households declared this situation; as shown in Fig. 2.

In turn, local governments constitute another level of government, which are made up of 196 provincial municipalities and 1,671 district municipalities, these governments have among their main functions: to comprehensively plan local development and territorial ordering, at the provincial level, thus how to permanently promote strategic coordination of comprehensive district development plans; Similar to regional governments, due to their autonomy to carry out activities in recent years, corruption cases in public services have increased [37, 38].

Fig. 3 shows the current situation and shows how the corruption network manifests at different levels of governments, emphasizing the corruption analysis in regional governments. The basic services or needs that citizens have are essential for the social development of Peruvians, it is there, where regional governments, through specialists, collect these needs to be evaluated and solved according to the problem. It is at this point where Public Investment Projects (PIP) are raised and the first incidents of corruption are perceived, where some consultants, public managers (Invierte.pe - National System of Multi-annual Programming and Investment Management) and advisers could present insufficient technical or managerial knowledge. Other incidents that exist are low resources and probably have officials without expertise. Furthermore, the procedures are cumbersome procedures with long duration in the management of the PIP.

The management of the PIPs is worked jointly between the Local Governments (LG) and the Regional Governments (RG) so that they can be managed in the technical areas of the ministries and approved by the Central Government (GC). However, it is here where the problem of corruption is exacerbated (see legend routes), where mayors, governors, use various media or intermediaries such as brokers, congressmen or government allies for the approval of the PIP; for this they use laws, regulations or addenda to misuse the economy of the Peruvian Government [39]. It is for this reason that the economic losses suffered by Peru due to corruption problems are around 10% of the annual public budget, exceeding three billion dollars. Therefore, it affects a tenth of the financial resources that are destined to health, infrastructure, administrative expenses, security, and education for the benefit of citizens.

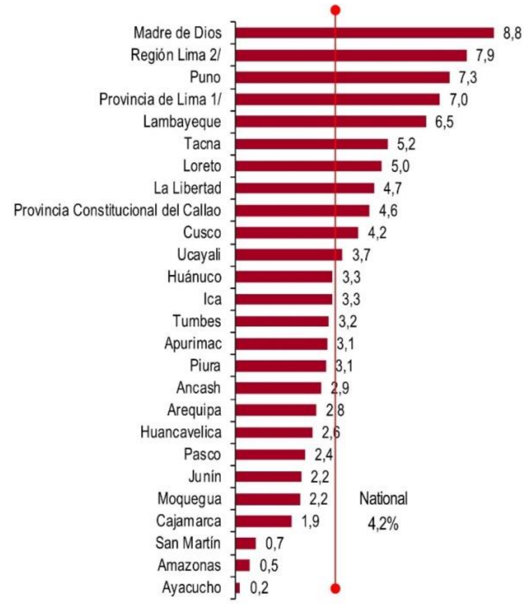

Fig. 2. Corruption Index in the Regions of Peru.

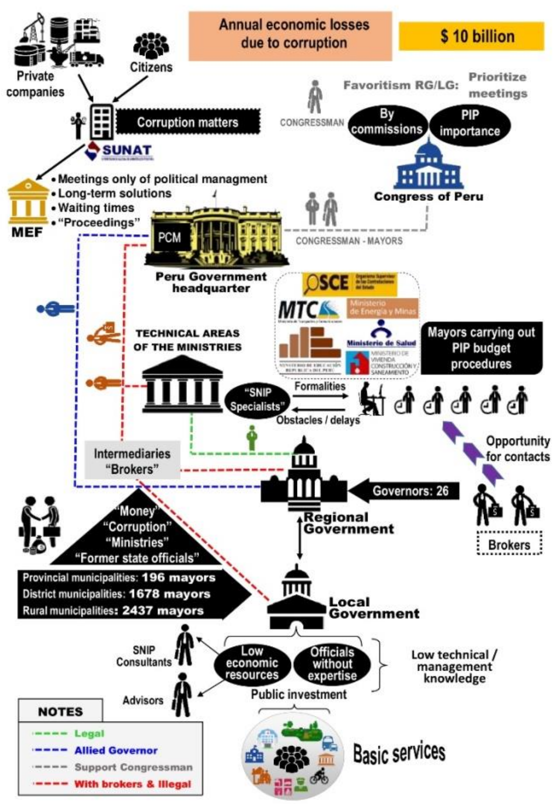

Fig. 3. Scenario of Interaction of the Players in the Corruption of the Regional Governments.

IV. Interaction Processess for an Anti-Corruption System

In the analysis of the current situation of corruption, it is highlighted that it has a high negative incidence in the national and regional government; affecting both its image, its management, and especially the population. Therefore, Fig. 4 shows the approach of an analysis model to reduce corruption for Regional Governments, using information technologies, positioning an anti-corruption application architecture module.

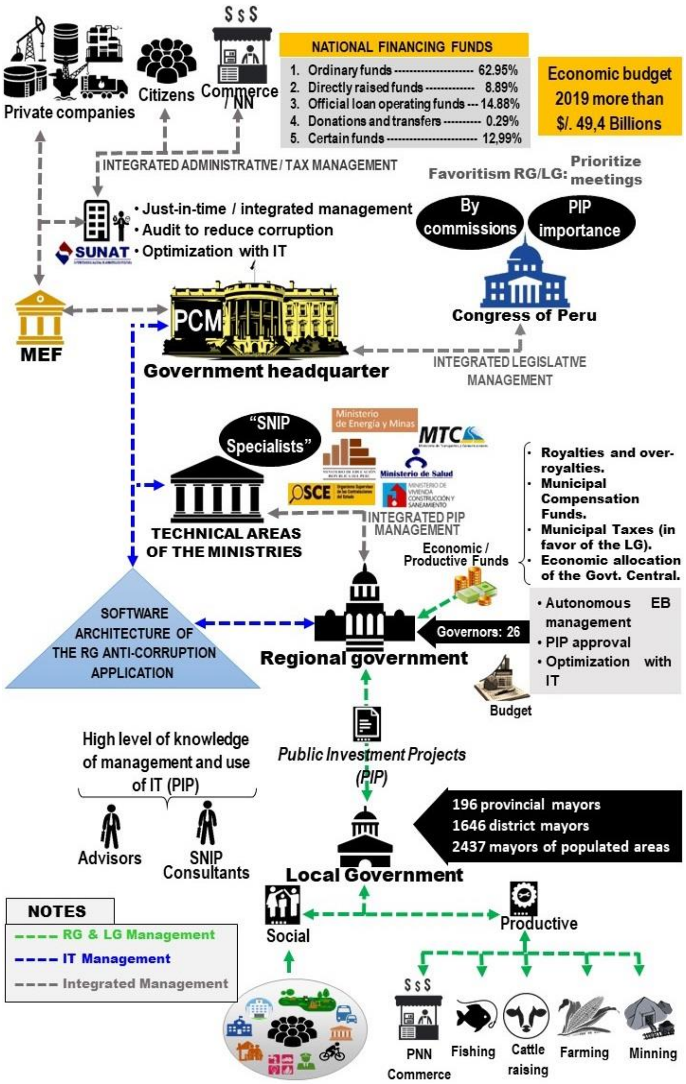

Fig. 4. Players and IT Interaction Scenario Against Corruption.

Due to the decentralization policy, the Office of the Presidency of the Council of Ministers (PCM) of the Government and the Ministry of Economy and Finance (MEF) annually agree funds to allocate to the Regional Governments, made up of transfers from the national government (from from all sources, that is, general resources, tax, royalties, customs revenues, etc.), financial income and own income from the collection of fees or rights. These funds should be directed to the development of the regions and promote science, technology and innovation. Therefore, these data are very important as input to the information system. Likewise, the technical areas of government ministries maintain a classification and prioritization of various areas within their field of action. So they interact with the Regional Governments to work together in the development of the regions. However, the Regional Governments have autonomy and under this operating framework corruption can potentially occur.

Currently, due to the low socio-economic situation of the majority of the population, the government prioritizes the management of basic services or to cover social needs, which are of high importance for the development of the regions. However, the productive management that Local Governments must have in conjunction with Regional Governments is being neglected in order to increase the regional contribution to national productivity, prioritize projects for the development of the region and promote activities related to science and technology. It should be noted that all this is minimized by the problem of corruption. In this situation, it is necessary to incorporate a module of the anti-corruption application architecture, to carry out a transparent management of the financial aspects and expected results in the various PIPs, and thus reduce the corruption index in the Regional Governments.

The resources and data considered to have an orientation in the architecture of the anti-corruption application for Regional Governments are the following:

- Budget allocation data for all Regional Governments.
- Corruption crime data.
- Financing data for political campaigns.
- Statistical resources or management information.
- Administrative management resources.
- Funds of the contracting processes in the Regional Governments.
- Integration resources between institutions.
- Funds for citizen participation in Regional Governments.

V. Data Structure and Resources of the Software Architecture

Fig. 5 shows the structure of data and resources for the development of the software architecture of the anti-corruption application. In order to operate and carry out information transparency action, the architecture must incorporate data from several sources as the National Office of Electoral Processes (ONPE) on the funds that political organizations use for their electoral campaigns, as well as data from Ministry of Justice of the judicial cases that are taking place and involving authorities and their family, friendship and business environments, from PCM on the transfer of funds for the regions from the central government, from the Supervisory Agency for State Procurement (OSCE) regarding procurement and contracting, and other data. On the other hand, it is very important to make the comparison with the information that comes from the Office of the Comptroller General of the Republic, since it is the institution in charge of controlling the country's public assets and resources.

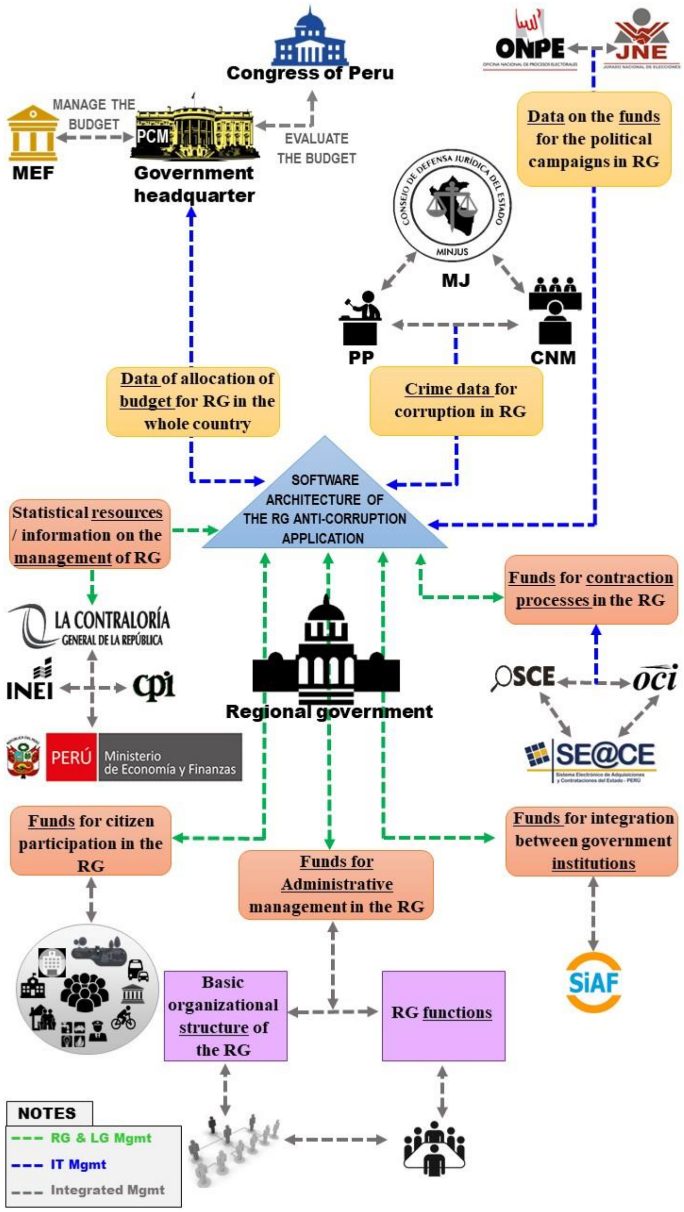

Fig. 5. Data and Resources for the Architecture.

For the development of the architecture of the anti-corruption application, the approach is made to the levels of data processing and presentation. Therefore, it is considered that the following elements must be integrated:

A. Data Processing Level

- Budgets
- Financing
- Crimes
- Government contracts
- SIAF integration
- Administrative management (Regional Governments)
- Citizen participation
- Statistics / information from institutions. Regulators

B. Presentation Level

- Economic situation modulePolitical parties module
- Corruption module (court cases / Notifications)
- Contracting module (PIP notifications)
- Management module (reports, production and social)
- Partners (user registration - rating system)
- Citizen participation (services and transparency)
- News (give your opinion / vote, News and learn more)

Fig. 6 shows the software architecture, where the application database collects the data with relevant information for subsequent analysis, coming from the multiples resources (databases) from various organizations.

A key element in the anti-corruption enforcement is the transparency of government information. Therefore, through a Web service, all government information such as government budget, corruption statistics, budget, sources and activities of political organizations, government contracts and so on, is made publicly accessible.

At the logical processing level, data analytics and control of the information collected on the application server are performed. Before this, data analysis with a large volume of data is carried out, firstly to perform the capture, management and processing of data with low latency, and social networks can be added to add perceptions, complementary data, etc. In this way, artificial intelligence (AI) drives the complexity of the data through new forms and origins of the data. Advanced analytical techniques are incorporated, such as text analysis, machine learning, predictive analytics, data mining, statistics, after data conditioning.

Subsequently, correlations are found between them, the resulting information is prepared to show trends, summaries and comparisons of activities (works, investments, progress, etc.), budgets, government contracts and others. Thus, the adequate information can be made public for the population and available to the political authorities for better and more timely decisions. Likewise, it should be noted that public information through the Web service may be usable for academic research studies, interactive systems with the citizen, background monitoring of candidates and political and government authorities.

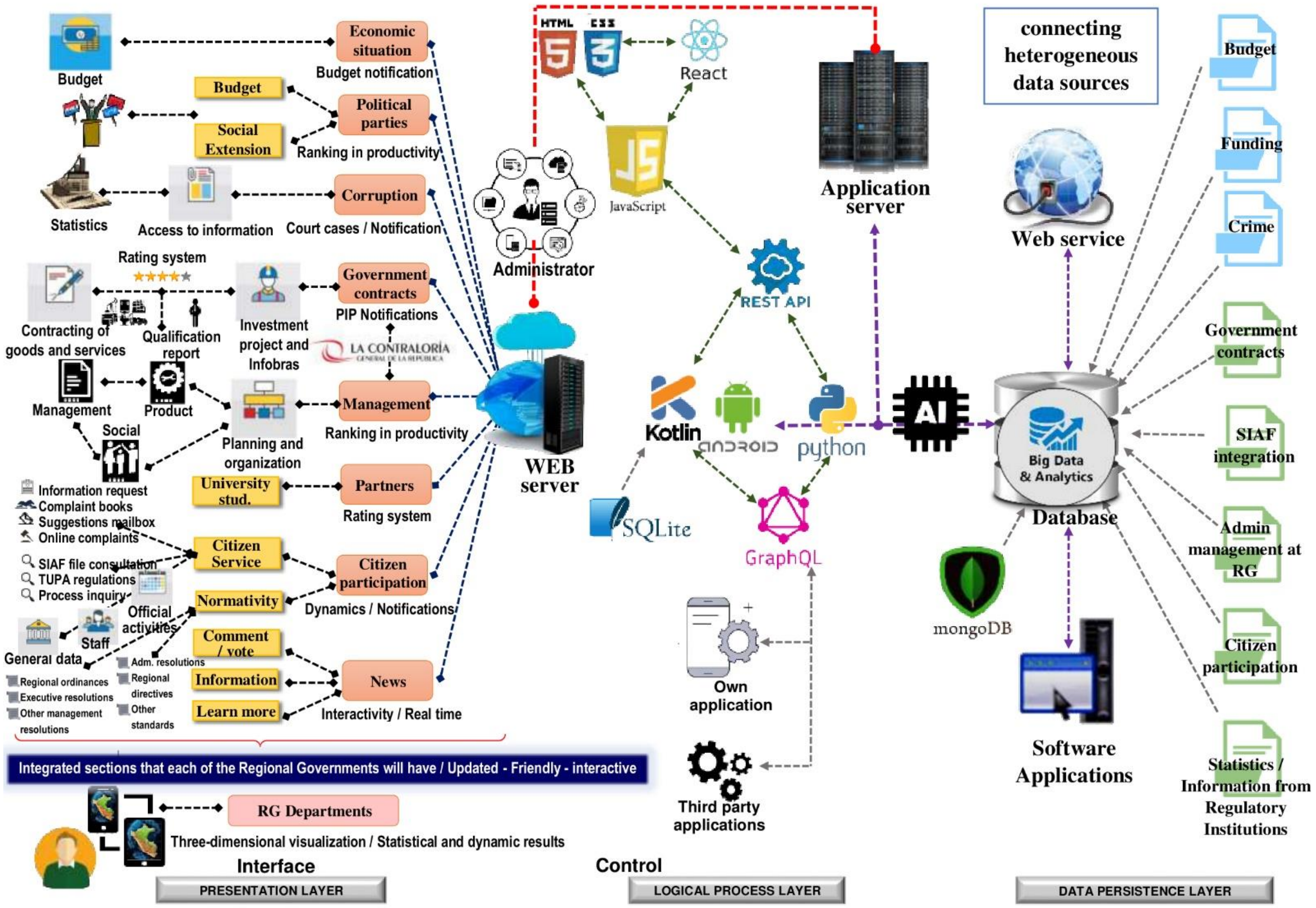

Fig. 6. Software Architecture Design.

VI. Conclusion and Future Works

Corruption represents a systemic phenomenon, affects morale and ethics, generates discouragement in the population, affects the poorest population, and causes a large amount of resources to stop being used for project development, especially those aimed at closing gaps, serving the basic needs of the most neglected population. In this sense, an analysis of corruption in regional governments has been carried out from a current situation; considering statistical studies, management areas, legal aspects and incidents of the IT.

The resources and data necessary for the anti-corruption software architecture have been highlighted. Consequently, the structure of this architecture has been proposed considering data on budgets, crimes, financing, administrative management resources, government contracting processes, citizen participation, integration of institutions, statistics and information. Finally, the levels of presentation of the required modules, data processing and logic are established.

Given the susceptibility and complexity of the processes involved at the regional government level, it is considered that the implementation of the proposed software architecture is developed and implemented in phases, being able to integrate data analytics and machine learning tools to obtain greater precision of the indicators and medium and long-term projection for better decision making.

As new scenarios appear, such as the health emergency due to the COVID-19 pandemic, the conditions exist for other possible corruption mechanisms to appear. In this sense, the new modalities must be analyzed and the appropriate operations must be included to update the proposed architecture.

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Ontology-based Course Teacher Assignment within Universities

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***Abstract*—Educational institutions suffer from the enormous amount of data that keeps growing continuously. These data are usually scattered and unorganised, and it comes from different resources with different formats. Besides, modernization vision within these institutions aims to reduce human action and replace it with automatic devices interactions. To have the full benefit from these data and use it within the modern systems, they have to be readable and understandable by machines. Those data and knowledge with semantic descriptions make an easy way to monitor and manage decision processes within universities to solve many educational challenges. In this study, an educational ontology is developed to model the semantic courses and academic profiles in universities and use it to solve the challenge of assigning the most appropriate academic teacher to teach a specific course.**

Keywords—Semantic; university ontology; academic profile; syllabus; course-teacher assignment

I. Introduction

Many Organizations in recent years have benefited from the role and impact of the Semantic Web to support decision making and planning processes. In education, Universities have tried to follow the modernization and compete with each other. This step caused many challenges in the domain of education. One way to win the competition is to replace the old traditional systems with modern technologies.

Semantic technology has been used to present data within many universities for the purpose of solving the challenges in the educational domain. As an instance, it has been used to optimize evaluation processes and decision making. Although the noticed use of semantic in the educational field, this technology still has not covered several possible areas.

Higher Education Institutes (HEI), especially Universities, are producing Knowledge continuously; thus, the created academic and administrative materials must be stored in record. Because of the enormous amount of information received by higher education institutions and the distinctive features of heterogeneous information systems that can vary within the same organization, the use of knowledge representation technologies makes systemic information important [1].

The main objective of this study is to use basic concepts and relationships in ontology to exploit the enormous amount of unstructured data in universities by building a university ontology. Besides, the proposed ontology is used to facilitate the process of assigning the courses to teachers within universities, as the complications related to this process are considered one of the most important challenges that appear frequently at the beginning of each academic year.

The study will be applied to King Abdulaziz University (KAU) in Saudi Arabia and concentrated on the Faculty of Computer and Information Technologies (FCIT). Additionally, the proposed framework would be considered to be smart enough to be compatible with domain data and to conduct resource matching and analysis.

This paper is organized as follows: Section 2 mentions the challenges in higher education. Then, recent works for university ontologies are discussed in Section 3. After that, the steps of developing the ontology are described in Section 4 including the evaluation. The main results and the future works are discussed in Section 5 followed by the conclusion in Section 6.

II. Related Works

A. Challenges in Higher Education

Higher Education is considered as the core of building the future in the whole wide world since it produces the employees for all institutions in different specializations. So, it needs to be provided with all the elements that guarantee efficient performance. Higher education involves various practices not only in teaching and learning but also in researches, employment, and decision making.

During the last decade, a modern vision of education has spread over the educational institutions which force most of the universities to move to a new education [2]. This modernization led to several challenges that require replacing the traditional information systems with the new techniques to solve them. Therefore, many of these challenges have been addressed by several researchers. Besides, different improved systems have been produced to solve these problems.

The most common challenges in higher education were reviewed in [3] and [4]. The author in [4] represented 20 challenges based on the recent appeared changes in higher education, students, and learning style over the last decade. The most significant challenges the author summarized are as follows:

- Quality of learning and teaching.
- Quality of research.

- Accreditation.
- Compete and collaborating globally in research and talent.
- Student retention.
- Assessment.
- A new generation of staff.
- Group formation for learning and teaching.
- Higher education governance and management

Solving these challenges starts with the correct use of the available information across institutional repositories, as the author has mentioned, and specifies what information can be shared [5].

The study in [3] has examined the use of big data and analytics to address higher education challenges. The paper classified the current trends affecting higher education as economic, technological, educational, and social changes. These changes cause challenges related to academic programming, research, teaching, and learning. The researcher argued that a huge amount of data in a different format from different sources is generated all the time which leads to scattered and difficult to retrieve data. Using big data and analytics methodologies improve the use of these data and help in making better decisions within educational institutions.

Several studies have demonstrated many systems that aim to solve problems in higher education. Some of these studies have used single sources and others have used citation and external open data. The semantic technology was one of the leading solutions that were applied in different aspects of education.

This study focuses on the challenge of assigning the most proper academic teacher to teach a new course. It is one of the popular challenges universities are facing continuously. It depends on matching course contents with resource expertise. Every time, traditional processes are used by the head of departments to decide the best matching. Usually, the first step is reading the contents of the course, topics to be taught, practical material, etc. Then, the CVs of faculty members are checked by focusing on their research interests, scientific publications, teaching experience, etc. The matching results are ordered in different ranks/marks for different faculty members. After that the best possible one is assigned. Performing this job manually on a huge amount of data is time-consuming and could produce inaccurate results. Also, the increase in the number of Ph.D. holders' staff within universities and the amalgamation in their interested research areas makes the decision of the courses' distribution process more complicated.

On the other hand, the proposed ontology can manage the need for collaboration between the university's departments and faculties. Every teaching term, for different reasons, some faculties have a shortage in the number of their staff while the number is excess in other faculties. By matching the topic of any course with any academic teacher profile that has the same specialty within the university the problem could be solved.

B. Educational Ontologies

In many cases, the data at hand is represented in semi-structured forms such as the tabular representation that is found in documents, spreadsheets, and on the web database. This kind of data, not similar to relational databases, follows a simple structure with no schema represented or specified. This means that humans can understand these data easily while machines cannot deal or process them since it is not in a formal representation and not backed by a specific schema [6]. Through ontology, data are available in digital form, which can be used by people as well as machines for sharing and developing knowledge-based systems [7].

Wading into using Semantic Web technologies in education would be essential because of the nature of the educational data that can create useful opportunities for educational institutions to improve their performance. So, educational ontologies can be used as a solution in many aspects of education since it can overcome the overloading information problem. During the past decade, the technology of the semantic web has been used by a significant number of studies within the educational domain which play a core role in solving most complicated challenges in different fields, such as information integration and sharing, web service annotation and discovery, and knowledge representation and reasoning [8].

Although the subject area of ontological technology in education is comparatively new, efforts have revealed that ontology-based tools and applications offer significant educational assistance and become one of the smartest research fields in education technology.

The study in [9] shows the development of a semi-automated educational instructor to help students in choosing learning paths (consisting of a collection of courses that outline the specific curricula) to complete a certain professional profile. They developed the Academic Tutor bearing in mind the situation of an Electrical Engineering Curriculum described by ontologies, a Semantic Web system that offers a logical and formal definition that people and machines can understand.

An Ontology-based Personalized Course Recommendation (OPCR) semantic recommendation model is suggested in [10]. The purpose of this system is to support students to pick the best curriculum from the vast number of courses accessible on the internet that suit their individual wishes. Therefore, the system uses an educational ontology method to seek similarity in student and course profiles considering future work for every student. Based on the outcomes and user feedback, OPCR has increased the reliability of recommendations relative to the matching approaches used in conventional recommendation systems for keywords.

Moreover, the Open University Is investigated in [11]. It has used semantic technology to describe information about published materials, teacher research work, titles, courses, and audio-visual educational resources. These data have been reusable and accessible to others by providing a SPARQL endpoint. Since some universities have moved from traditional learning to digital learning by providing Open Educational Resources (OERs), the linked data vision demonstrated by software interface enables a new generation of OERs and Open Course Ware (OCW) that can be semantically described and connected with other data and discoverable sources. These resources include tools and materials needed to support education to be freely accessed, reused, modified, adapted, and shared by anyone. The researchers introduced a vocabulary using W3C's RDF technology called Linked Open Course Ware Data (LOCWD). It links OERs, open licenses, OCW repositories, and other academic information using the web. The main idea of these vocabularies is to connect the described OCW domain with Datasets in the LOD cloud.

An ontological approach for semantic modelling of curriculum and syllabus in higher education is proposed in [12]. This study aims to introduce a learning ontology model that improves the usability of curriculum, syllabus, learning subject, and learning materials. Also, it develops services based on the proposed approach such as aligning curriculum, classifying syllabus, retrieve concepts of syllabuses and curriculum semantically, and recommending adaptive learning paths. This curriculum ontology can be used to combine numerous department curricula of the same discipline or to allow several subjects to converge. Also, a classification scheme for the syllabus and learning ontologies were provided by this ontology.

Another educational ontology is proposed in [13]. It is semantically modelling the main concepts in curriculum and syllabus in higher education considering the national and international accreditation rules.

The developed ontology in the next section will use the advantages of semantic and describe the needed educational data to solve the assigned educational challenge.

III. Ontology Development Method

Many methods and tools have been emerged to develop ontology based on the purpose of the educational ontology. The design of our ontology is following the guideline mentioned in [14] and [15]. It includes the steps in Fig. 1 below:

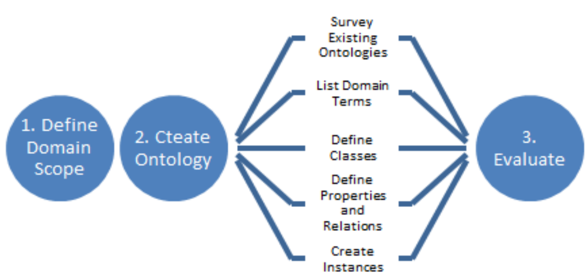


Fig. 1. Ontology Development Methodology.

A. Define the Domain

1) Selected scenario: This proposed ontology aims to treat the problem of assigning academic teachers with courses using semantic technology. So, course description and details, and the faculty profile are transferred from unstructured textual data to RDF format. Then, we can perform the reasoning on the resulting RDF data by applying SPARQL queries and find the best possible resource for a course in minimum time with the best suitable match.

As an essential process, before starting developing the ontology, we need to review the official documents that represent academic staff profiles and courses' descriptions to elicit concepts and identify the main relationships.

This study will be applied to the KAU data as a proof of concept and, particularly, the Faculty of Computer and Information Technologies (FCIT) will be the case study. The ontology has to describe staff committees and courses of KAU.

a) KAU Data Design: In the Kingdom of Saudi Arabia (KSA), all the institutes of higher education, including KAU, must be accredited by the National Commission for Academic Accreditation & Assessment (NCAAA) as requested by the Ministry of Education (MoE). Therefore, they are considering the NCAAA rules when they prepare their data for accreditation. The NCAAA accreditation and quality assurance criteria are designed in compliance with international standards and apply to Saudi Arabia's requirments [16].

b) FCIT General Information: FCIT consist of three main departments that are:

- Department of Computer Science
- Department of Information System
- Department of Information Technology

Each department offers different programs. The focus of this paper is on the bachelor courses only. The number of courses offered by the faculty for bachelor degrees is shown in Table I. Also, the table mentions the number of academic members of FCIT. Each department within FCIT has a number of academic teachers who are holding different degrees as follow:

- Ph.D. holders
  - Professor
  - Associated Professor
  - Assistant Professor
- Non-Ph.D. holders
  - Lecturer
  - Teaching Assistant

TABLE I. FCIT COURSES AND ACADEMIC STAFF DETAILS

Department	No of academic teachers	No of Ph.D. holders only	No of bachelor courses
Computer Science	109	51	44
Information Science	99	45	41
Information Technology	106	53	34

c) Syllabus: It is an organized document that is prepared by the teacher to represent the main information about a course. It can be used as a reference and guidance by both teachers and students. Currently, there is no unique format for representing the syllabus in universities around the world. Syllabus is usually represented according to NCAAA format using the following components:

- Course code
- Course Credit
- Prerequisite Course
- Course Classification
- Class Schedule
- Textbook
- Grade Distribution
- Last Articulated
- Relationship to Student Outcomes
- Course Learning Outcomes (CLO)
- Coordinator(s)
- Topic Coverage Durations

d) Academic staff profile : It is a document that contains all the official information about an academic staff. It focuses usually on background in educational administration, program management, academic skills, degree, expertise, publications, and interesting research area. There is no stable form of the academic staff CVs. Each educational institution has a different template to organize its staffs' information. The following components are used to describe the academic staff profiles in NCAAA format:

- Staff name
- Staff rank
- Department
- Department Contact Information
- Highest Degree
- Scientific and Professional Affiliation
- Academic and Professional Experiences
- Certifications and Trainings
- Research Areas of Interest
- Recent Publications (Last 20 Years)

2) Competency Questions: Competency questions (CQs) is a technique that is used to test the efficiency of an ontology. It consists of several questions that should be answered by the information provided by the ontology. Basically, these questions are sketched to define the scope of ontologies and specify the requirements and the needs the ontology will fulfill. On the other hand, they can be used later to evaluate the ontology. The most important CQs are:

- What are the courses provided by a given department?
- What is/are the prerequisite course(s) of a given course?
- Who is/are the coordinator(s) for a given course?
- What are the topics of a given course?
- What are the learning outcomes of a given course?
- Which course(s) cover a given knowledge area?
- Who can teach which course?
- Which academic teacher is the best to teach a specific course?
- What are the interested search areas for a given academic teacher?
- Which course is best to be taught by a specific academic teacher?

Table II shows some examples of CQs with their expected answers.

B. Building the Ontology

After reviewing the textual official documents, they will be transferred into the RDF format. Then SPARQL queries will be applied to extract suitable answers to our research questions.

To develop our ontology, it is important to choose a suitable ontology editor. Protégé editor is chosen since it is considered as one of the best common ontology creation and information demonstration tools built over nearly 20 years [17].

TABLE II. EXAMPLES OF COMPETENCY QUESTIONS

CQs Example	Expected Answer
• Who can teach which course?	A list of all the academic teachers that possibly can teach each course in the department depending on their interested research areas that match the topics of each course
• Which academic teacher is the best to teach a particular course?	A list of all the academic teachers that possibly can teach a course depending on their interested research areas that match the topics of the particular course
• Which course is best to be taught by a particular academic teacher?	A list of all the possible courses that can be taught by an academic teacher according to the topics

1) Reusing existing ontologies: Most of the development methodologies recommend considering reusing existing ontologies before starting a new one. This step can help with two faces. First, if a developer finds an ontology that matches his requirements, he can save time and reuses it. Second, he can extend his experience in the development process when it is impossible to find a matched one.

To decide the ability to reuse any of the current ontologies, several related works reviewed to evaluate whether they can model our information. The possibility of reusing the selected ontologies was examined based on the following criteria:

- The purpose and the core concepts of the ontology
- The structure of the ontology (the vocabularies and the relations should meet our needs)
- The language used to create it (the ontology should be available in RDF format)
- The tools used to create it
- The license (the selected ontology should be legally allowed to be reused by other researchers or institutions)
- The availability (is it available online or not)

The literature review below focuses on the current studies describing syllabus and curriculum semantically since they are considered as a skeleton to any educational ontology.

Academic Institution Internal Structure Ontology (AIISO) is a university ontology that emphases on the university domain's systemic perspective. It describes the roles that people within an academic institution play by connecting with Participation ontology and FOAF.

BBC curriculum ontology is considered as a core model for describing the British national curricula using RDF technology. Besides, it organise learning resources and makes them available to the user to discover the content of the national curricula [18].

Higher Education Reference ontology (HERO) is described in [14]. The aim of building HERO is to offer a university domain template of consistent information that can be used as a basis for deriving more precise ontology from the university domain. So, this ontology of reference is intended to be used to define the higher education domain in direction to offer a consistent knowledge of the domain of interest to be shared and reused between diverse users, different communities and different universities. HERO was introduced in OWL 2. Subsequently, it is Reference Ontology, it has a broad and deep exposure of the university domain; in other words, ontology designates numerous features of the university domain such as organizational structure, administration, staff, roles, incomes, etc. The object of this reference ontology is to define any university as important or at least favourable.

Semantic Web for Research Communities (SWRC) ontology describes the main concepts within research communities. As mentioned in [19], the ontology contains six top level concepts, named Publication, Person, Organization, Event, Topic and Project. These concepts were modelled using OWL-DLP ontology language. The main aim of SWRC is to find relations between researchers.

Demartini and his colleagues in [20] have used Bologna reform process for higher education studies to develop an educational ontology called Bowlogna. This ontology describes entities and relations in an academic institution and it aims to support communication and collaboration between universities among European countries. Beside it improves student mobility since it focuses on grading and student's study tracking systems. Additionally, the definitions for all the concepts in Bowlogna ontology are available in the most important languages the used commonly within the European higher education: German, French, Italian and English. This ontology consists of two parts: public part that consists of information that can be shared and private part that stores information that should not be visible to other institutions.

Curriculum-Course-Syllabus-Ontology (CCSO) is an educational ontology that produces the main concepts in higher education (Curriculum, Course, and Syllabus) semantically to support teaching and learning processes within universities [13]. The developers of this ontology have described classes and properties based on the rules of Hellenic Quality Assurance & Accreditation Agency (HQA) accreditation model in Greece. They also cited the 2013 Computer Science Curricula, a study by the Joint Task Force ACM / IEEE-CS that provide critical guidance on curriculum design and development for computer science undergraduate programs.

CURONTO is another educational ontology that has been designed by researchers from King Saud University (KSU) in Saudi Arabia [21]. The researchers have applied national and international standards to develop their ontological model for curriculum representation. It has been used to promote the review and evaluation of a particular course in higher education. CURONTO supports the decision-making process, finding gaps, recognizing repetitions, and identifying standards based on connecting relationships between learning outcomes, learning units, and overall course objectives. This ontology is applied to the Bachelor's Program in Information Technology at KSU as a case study.

OLOUD ontology is a collection of existing ontologies linked to describe course information at Hungarian universities. These data can support the management of the integrated university and building web applications. Also, It helps both students and teachers by providing services such as personal timetables, long time planning, course navigation, university resources usage and other types of services [22]. The main concepts in this ontology are described under the Bologna Process to ensure the compatibility for the European education system.

Table III compares the main terms defined in the existing ontologies.

TABLE III. COMPARING THE MAIN TERMS OF EXISTING ONTOLOGIES

Ontologies	Terms						
	Course	**Syllabus**	**Faculty**	**Department**	**Teaching Staff**	**Publication**	**Learning Outcome**
HERO	√	X	√	√	√	√	X
AIISO	√	√	√	X	√	X	X
Bowlogna	√	√	X	X	√	X	√
BBC Curriculum	√	√	X	X	X	X	√
CCSO	√	√	X	√	√	X	X
SWRC	X	X	X	√	√	√	X
CURONTO	√	√	√	X	X	X	√
OLOUD	√	√	X	X	√	X	X

This revealing process proved the need of creating an ontology from scratch. The existing ontologies can be used as a guideline to model the main concepts in our ontology since they are not covering our requirements. The main reasons of this decision are summarized as follow:

- None of the current ontologies can serve our domain completely to achieve our intended aims
- Universities represent their data using different standards forms. Therefore, the structures of their ontologies are not compatible with our domain
- Although some existing ontologies can be useful, unfortunately, they are not available online
- Most of the reviewed approaches can be similar or either can extend each other. However, most of them describe general points or detail that can be modified or extended in our ontology

2) Specification Phase:

a) The Domain Terms: Before building the main class hierarchy, it is initially important to list all the terms that describe our domain. All the possible words that can describe the domain of education are gathered with the consideration of the CQs, the NCAAA rules, and the policy of KAU. Besides, it is necessary to inspect the terms defined in the existing related ontologies and use them as guidelines to list our terms. Table IV shows the basic terms that we expect to define in the proposed ontology.

b) Classes amd the Class Hierachy: Probably, this is the main step of the development process. To design the class hierarchy, we need to refer to the list of terms in Table IV and choose the most proper concepts that can represent the super-classes and sub-classes. As a result, the total number of the classes that have been described is 15 as shown in Fig. 2.

3) Conceptualization Phase: Since the classes alone are useless, this phase aims to add links between the classes that allow the ontology to answer our inquiries.

TABLE IV. DOMAIN TERMS

Syllabus	**Teaching Staff**
Course	Faculty
Department	Faculty_member
Syllabus	Taching_Staff
CLO	Research_Work
Text_Book	Project
Topic	Publication
Evaluation	Interested_research_area
Coordinator	

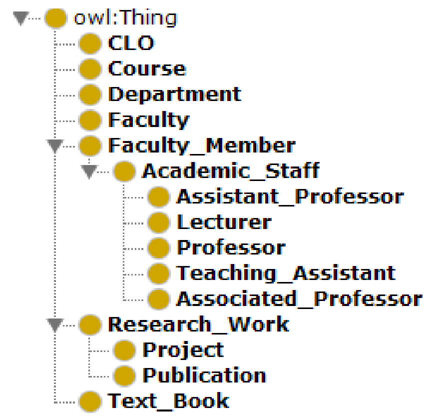


Fig. 2. Ontology Class Hierarchy.

a) Relationship between the Classes: This ontology contains two types of properties. Relationships between the classes are presented using 14 object properties. Table V lists the most important object properties. As an instance, "coordinate" and "coordinated_by" are two inversed object properties that describe the relationship between the classes "Academic_Staff" and "Course". On the other hand, there are 26 data properties to describe information about each individual as shown in Fig. 3. For example, "course_title", "course_topics", and "course_description" are used to define instances of the class "Course".

TABLE V. OBJECT PROPERTIES IN THE ONTOLOGY

Object Property	**Domain**	**Range**
belongs_to	Course	Department
coordinate	Academic_Staff	Course
coordinated_by	Course	Academic_Staff
has_course	Department	Course
has_department	Faculty	Department
has_member	Department	Faculty_Member
member_of	Faculty_Member	Department
part_of	Department	Faculty
prerequisite	Course	Course
prerequisite_by	Course	Course

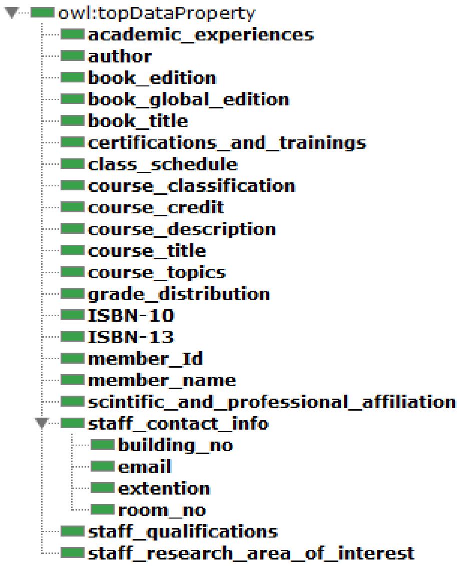


Fig. 3. Data Property Hierarchy.

4) Formalization and Implementation phase:

a) Create Instances: After creating all the needed classes and properties and completing the ontology model, instances (individuals) can be described. This step involves selecting a unique name for each individual, specifying the class to which it belongs, and defining its attributes values (data properties). Fig. 4 summarizes part of the ontology metric, including the number of the created individuals.

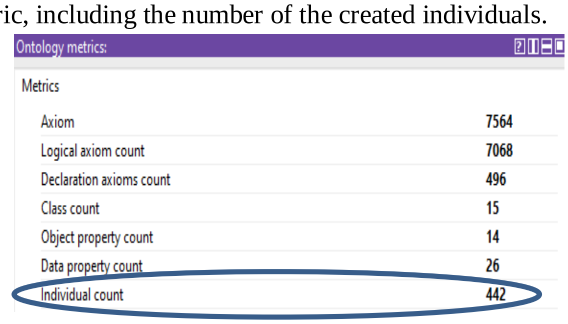


Fig. 4. Individuals in the Ontology.

C. Evaluation

In this critical step, the CQs are used again to find the results of our research questions and to evaluate the ontology. SPARQL queries are extracted from the questions then executed using the feature tab "SPARQL query" in Protégé. Table VI shows the most important examples of SPARQL queries that used in the evaluation process.

Using the CQs technique has confirmed the sufficiency of the knowledge represented in the ontology and shows how it could answer the queries that extracted from the CQs.

TABLE VI. EXAMPLES OF SPARQL QUERIES EXTRACTED FROM CQS

CQs Example	SPARQL Query
• Who can teach which course?	SELECT ?Department ?Course ?Teacher ?Topic WHERE { ?Course dss:belongs_to ?Department. ?Teacher dss:member_of ?Department. ?Course dss:course_topics ?Topic. ?Teacherdss:staff_research_area_of_interest ?Topic} ORDER BY ?Department
• Which academic teacher the best to teach a particular course (e.g. "CourseA")?	SELECT ?Teacher WHERE {?Course dss:belongs_to ?Department. ?Teacher dss:member_of ?Department. ?Course dss:course_topics ?Topic. ?Teacher dss:staff_research_area_of_interest ?Topic. ?Course dss:course_title ?aa FILTER regex(?aa, "^ CourseA ").}
• Which course is best to be taught by a particular academic teacher (e.g."Teacher1"?)	SELECT ?Course WHERE {?Course dss:belongs_to ?Department. ?Teacher dss:member_of ?Department. ?Course dss:course_topics ?Topic. ?Teacher dss:staff_research_area_of_interest ?Topic. ?Teacher dss:member_name ?aa FILTER regex(?aa, "^Teacher1").}

IV. DISCUSSION

To judge the accuracy of the results from the evaluation process, there is a need to build more SPARQL queries that return digit results to give a clear picture of the main results and to make a comprehensive comparison.

Hint, the evaluation was applied to the Ph.D. holders only since they are usually engaged in research activities and publish journals and conferences. Besides, the courses are taught by them when most of the non-Ph.D. holders are considered as teaching assistants. So, there are no records of their interesting research area. At the same time, all the academic teachers' profiles in the faculty, from all the degrees, have translated into RDF format for future processes.

To find the number of teachers who are allocated to teach courses, we used the query mentioned in Fig. 5. This query counts the teachers depending on their interesting research area that match topics of courses or if they are coordinators of any courses within the same department.

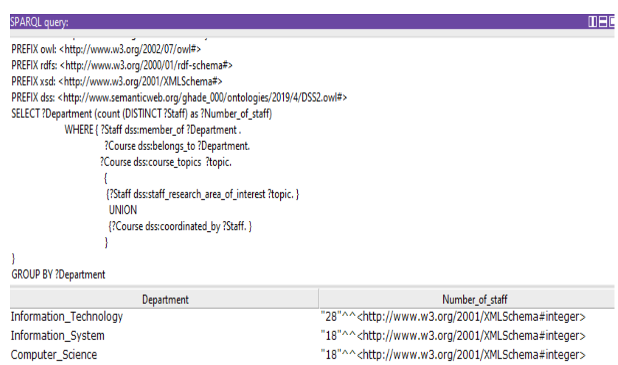


Fig. 5. Counting the Allocated Academic Teachers in Protégé.

By comparing these numbers with the total number of teachers (see Fig. 6); we find that only 40% of the academic teachers in the Information System department were allocated to teach courses when nearly 36% of the Computer Science department teachers are allocated. On the other hand, 53% of the academic staff members in the Information Technology department are allocated to teach courses from the same department.

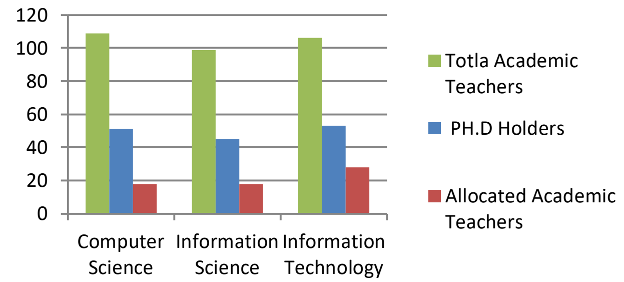
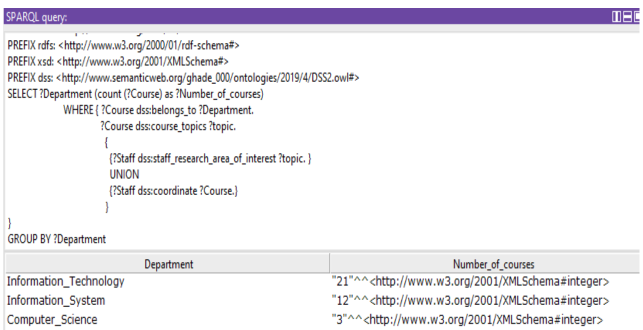


Fig. 6. Comparing the Number of Allocated Academic Teachers with the Total Number.

Fig. 7 below describes the SPARQL query that counts the numbers of the courses that are assigned to academic teachers in each department.



SPARQL query:

```
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX dss: <http://www.semanticweb.org/ghade_000/ontologies/2019/4/DSS2.owl#>
SELECT ?Department (count (?Course) as ?Number_of_courses)
        WHERE { ?Course dss:belongs_to ?Department.
                ?Course dss:course_topics ?topic.
                {
                 {?Staff dss:staff_research_area_of_interest ?topic. }
                 UNION
                 {?Staff dss:coordinate ?Course.}
                }
}
GROUP BY ?Department
```

Department	Number_of_courses
Information_Technology	"21"^^<http://www.w3.org/2001/XMLSchema#integer>
Information_System	"12"^^<http://www.w3.org/2001/XMLSchema#integer>
Computer_Science	"3"^^<http://www.w3.org/2001/XMLSchema#integer>

Fig. 7. Counting the Courses Assigned to Teachers in Protégé.

According to Fig. 8, more than half of the courses in the Information System department not assigned to any teacher since only 30% of them are assigned. Also, it is mentioned that only 7% of the courses in the Computer Science department are assigned to teachers. On the other hand, 62% of the courses are assigned to teachers in the Information Technology department.

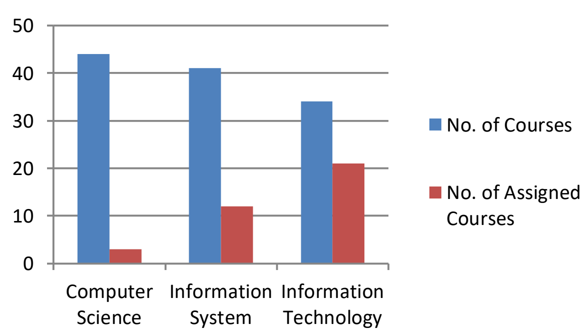


Fig. 8. Comparing the Assigned Courses with Total Number of Courses.

Although the percentages that are shown in the evaluation process are small, still using the semantic technology for allocating the best academic reference for teaching courses gives accurate and faster results than the manual process. So, the results show that more than half of the academic teachers would not be assigned to any course. At the same time, a large number of courses were not matched with any academic teacher. This keeps the need to use the manual process for these remain data.

By referring to the data, it is found that each teacher belongs to one of the cases below:

- Allocated teachers: the teachers who are listed in the results. e.g. "Teacher1" has been chosen to teach "CourseA" when we check the results we found that there is a match between the topics of "CourseA" and the research area of interest for "Teacher1".
- Not Allocated teachers: the teachers who are not listed in the results:
  - Caused by incomplete data: e.g. "Teacher2" has not been assigned to "CourseB" although he is teaching this course according to the manual matching. This is because the details for "Teacher2" are not completed especially the areas of interest record.
  - Caused by incompatible data: e.g. "Teacher3" has been missed in the results we have while he can teach "CourseC" according to his specialty, and his profile is completed. When we refer to his records, we found that his areas of interest are written as abbreviations when the topics are mentioned in full description.

That end up with the main reason why this shortage appears is that while the details of all the courses are completed, some academic teachers not describing their research areas of interest correctly or not mentioning them in their profiles.

As an initial suggestion to overcome this shortage, proper external repositories can be used to complete the missing data and rich the matching criteria by leveraging the semantic with linked data technique in future work.

V. Conclusion

Text Modernization spreads in the education domain in the last few years. This leads several researchers to find solutions for the challenges caused by this modernization. This work supports the decision-making process within universities by proposing an ontology that demonstrates courses and academic profiles semantically. Using semantic technology can make dealing with the continuously increasing amount of data, universities usually have, easier. The study aims to solve the challenge of allocate the most proper academic teacher to teach a new course. To apply this study, King Abdulaziz University was the case study focusing on the Faculty of Computing and Information Technology including its three departments that follow the NCAAA rules for documenting their data.

Developing the ontology consists of some processes. First, the domain was described to determine the scope of the ontology. Then, several existing ontologies were reviewed to test the ability to reuse them but, none of them was appropriate with our criteria so, the ontology was developed from scratch. According to the domain description, the textual data for 119 courses and 314 academic teachers' profiles are transferred into the RDF format. After that, the relations between these concepts were defined via object and data properties. To complete the vision of the wok, some individuals have been created.

The evaluation process included using the CQs technique. The test showed that although a significant number of courses and teachers have not been assigned, still the system gives accurate results. In the future, external repositories can be used to solve this shortage. The system can be extended to support more decisions within universities or to solve more educational challenges. Besides, it can be reused by other universities specially the Saudi universities that apply NCAAA rules.

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