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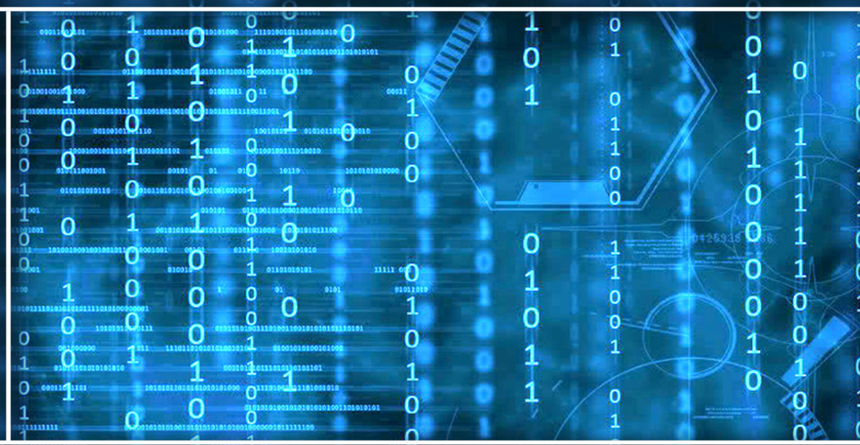

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Editorial Preface

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

Reviewer Board Members

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The Use of Gamification in Higher Education: An Empirical Study

István Varannai
Department of Information Technology
University of Miskolc
Miskolc, Hungary

Peter Sasvari
Institute of E-Government
National University of Public Service
Budapest, Hungary

Anna Urbanovics
Faculty of International and European Studies
National University of Public Service
Budapest, Hungary

***Abstract*—The use of gamification in higher education has increased considerably over the past decades. An empirical study was conducted in Hungary with two groups of students to investigate their behaviour while interacting with Kahoot! The results were analyzed based on the technology acceptance model. They indicate that the positive attitude, good experience and ease of availability contributed to improve student performance which strengthened the intention to use the application. Besides these, the perceived utility was positively influenced by the ease of use as consequence.**

***Keywords*—Gamification; education; Hungary; technology acceptance model; university student**

I. Introduction

Gamification has increased considerably over the past decades as video games have become more colorful and lifelike. Immediate interaction between the users and establishment of a rewarding system helped gamification become widespread in higher education. However several definitions of gamification have spread simultaniously, the most accurate is Deterting's definition. It identifies gamification as the design, implementation and use of game mechanics in nongame contexts [11]. This definition was used in the research because it fits to the set targets. The research was conducted among two groups of university students, IT and non-IT students, in order to measure the impact of gamification in higher education. In general, we can observe a growing demand for gamified applications which can be explained mainly by the potential of gamification to engage and motivate students during lectures [12]. The target of the research was to analyze the experience of IT and non-IT students concerning the method of gamification by filling out a survey in the Evasys online sytem. The preliminary condition was to get familiar with the Kahoot! application which was introduced to the students by one of the university lecturers. This application created competition during lectures and enhanced group learning. Students could get feedbacks on their results so a rewarding- punitive system was formed. Different external and internal factors of motivation came to the fore while playing with Kahoot! Affective feedbacks were influenced by the application as it put well defined targets in front of the players. Generally stating, gamification engages students to learn and enhance the development of positive learning attitudes [13]. The article aims to provide an overview of different factors of gamification and crawl correlations between them. The research is based on Davis's TAM model (technology acceptance model) of which main components are: use, utility, experience, attitude, intention and availability [2], [4]. Besides this, the article describes the possibilities of implementing gamification into higher education. The article is based on data of students of the University of Miskolc and the National University of Public Service.

This paper has been written with the support of the National University of Public Service in the framework of the priority project KÖFOP-2.1.2-VEKOP-15-2016-00001 titled „Public Service Development for Establishing Good Governance - Ludovika Digital Governance Research Group

First of all, we carry out a literature review and present the primary research and the Kahoot! application. In the remainder of this paper, we outline the research process and theoretical model used for the research. Finally, the discussion and summary of the results are given.

II. Literature Review

For the initial phase of the research, a literature review was done. The main focus was on the domain of education and science in general. The keywords were searched on databases related to the subject, including ScienceDirect and Scopus. The literature search revealed that the term gamification has spread steadily from 2010 internationally. While in 2011 only 15 documents were uploaded in the topic, it has extended almost 40 times by 2016 with 592 volumes. Altogether, in this period 1660 volumes were uploaded from 89 countries.

The research methodology is based on an article written by Maican, even though this article focuses on the comparison of different game-based application. With respect to the questionnaire and results it is a unique research [6].

III. Primary Research in the Topic

The target group of the research is the Z generation whose members were born between 1995 and 2010, so they actually form the majority of the university students. Given the characteristics of this generation, it is supposed that participating in a "gamified" lecture would not be difficult to them. Members of this age-group have already been born to a digitalized world so the smart tools make part of their everyday routine. Internet and online games are popular among them, but they are opened to adapt new technologies as well. Because of these, following Marc Prensky's definition they are called "digital natives" [9]. They have a different way of thinking compared to members of the previous generations as they get access to information faster. Their learning habits have changed as well. Ar regards to their communication, they spend a couple of hours online every day, so they get used to contact virtually with each other. We can observe that the frequency of Internet access depends on the age. From younger age groups to elder people, not only the proportion of Internet users but also the intensity of use within the users decreases. This means that among the elderly there are less internet users, and that the elder internet users use internet less than youth [8]. 90% of the members of Z generation are online every day, while only a small group say, they use Internet once a month at most or not at all. Fig. 1 shows the Internet usage patterns among the Z generation.

The birth of Z generation into a digital and technology oriented world creates a number of problems in the field of education as well because the teaching methods of the 20th century are not successful and efficient enough anymore. Introduction of gamification could provide a solution for the difficulties of education systems with respect to the digital natives. They are perfectly familiar with the conditions of the gamification technology and they use it as a part of their daily routine.

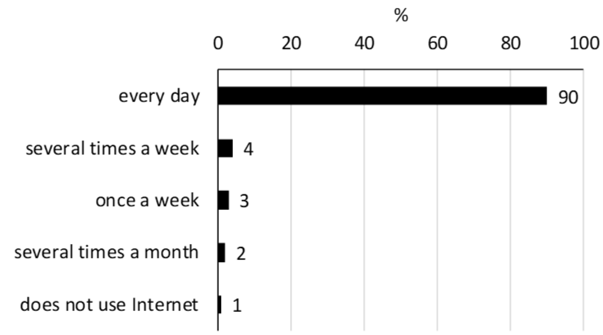

Fig. 1. Frequency of Internet use by the Z generation (Among telecommunication services and public users, based on 2016).

A. *Our Research Tool: Kahoot!*

We can observe multiple advantages of gamification in every field of life. Loyalty schemes give us the best examples. They are built up on this method, where the more you purchase, the more points you score and the higher reductions you get in case of the next shopping [7]. Customers are motivated to earn points to reach higher levels with higher reductions (e.g. bronze, silver, gold and platina level customers of telecommunication companies, or reductions for several frequent flyers of airways). With reference to the Nike, with its Nike+ application we can measure our results at running, our development in the sport, and even compete with others virtually while we can receive different prizes or video messages from famous athletes. The company could increase its income with 10% from the running stocks last year due to this gamified project [1]. Other example is the application of the Nissan Leaf's 100% electronic car where we can count the number of virtual trees which we can increase by driving energy efficiently. Altogether, we can see many creative and successful examples for gamified projects. We can observe gamification at language-teaching soft wares (e.g. Duolingo), or the Hungarian- developed gamified innovative e-learning systems (BeeTheBest, Redmenta). It can be stated that gamification motivates people to learn more using these applications, however only a few articles have been written about its impact on learning. In the research the Kahoot! application was used to measure this impact. We can observe a general competition between the players because the main aim is to skip always to higher level. Kahoot! uses competition as a motivating factor as well. Besides the web-based platforms, the application runs perfectly on tablets and mobile phones and the mobile application is available for both Andriod and Ios users. The following simplified flowchart (Fig. 2) provides an overview on how the Kahoot! works (prior registration needed).

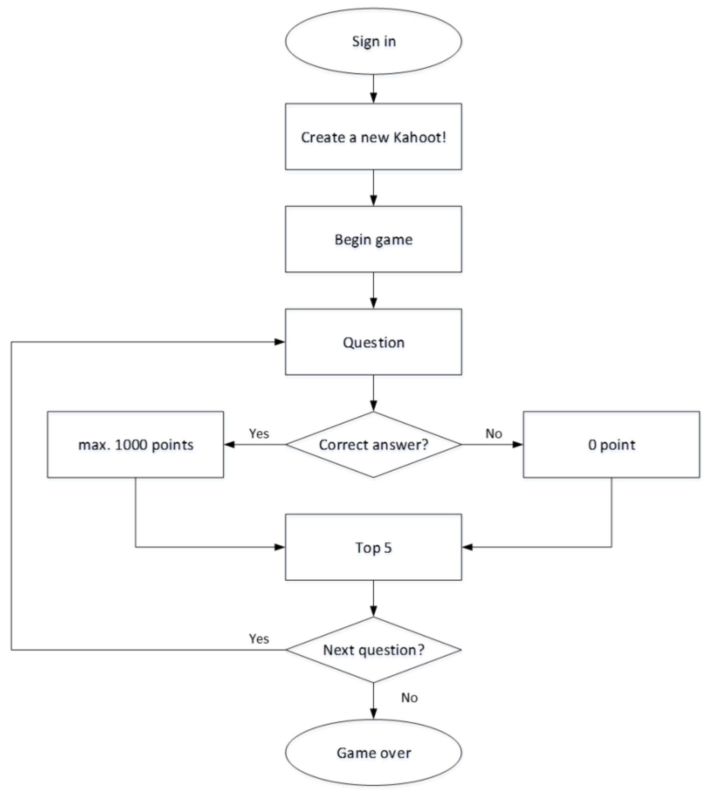

Fig. 2. Simplified flow diagram of the Kahoot! application.

After logging in we can prepare quizzes, but we also have the possibility to play with games which were prepared by others. In order to be more colorful, we can add different images and videos to our quiz. When playing only the internet access must be granted and a notebook is also necessary to screen the questions because they are not visible on the players' own devices. During the 2016/17 fall semester 1000 points could be scored for every right answer and 0 points for wrong ones. The points are also influenced by the reaction time so the faster you answer the more points you score from the total 1000. After responding each question, the top five players are displayed. If the game has not finished, the next question appears on the main screen. When the game is over, the lecturer can download the final results in an Excel spreadsheet, or can synchronize them to a Google Drive profile. Students log in using their Neptun code (unique identifier), so the players' list can be used as an attendance list as well. On the left side of the question we can find the remaining time, while on the right the number of received answers is presented. Students could participate in the competition once a week at the end of each lecture. The questions were linked always to the actual topic. They got 5-6 questions every week so the game was not too long but the high-level of motivation could be observed through the semester due to the awards. It can be observed that by the Kahoot! a balance between the internal and external motivation was found.

IV. Theoretical Modelling

In parallel with the increasing technological requirements the expectations grow. In order to reach the best quality, and satisfy every expectation several concepts have been developed which are called as quality measuring models and systems. They can be used to estimate future success or to eliminate potential faults. Their common feature is that they take into account the human element. The doctoral thesis of Davis in 1989 was written as a result of this process, which served to examine the link between the motivation and system characteristic. It is called the TAM, Technology Acceptance Model. The model consists of different motivation factors, and most importantly it is based on human attitude. Elements of the TAM model can be divided into subjective and objective elements. The subjective elements are e.g. the user acceptance and behaviour, while the objective elements are more measurable e.g. the use. According to the model, use of the new technology is defined by the cognitive (impacts of cognition) and the affective (emotional impacts) feedbacks as it is mentioned in Fig. 3.

Based on Fig. 3 it appears that technology acceptance has two determinants: the use should be simple and the recognized benefit should be high [6] [13]. The easier the use is, the higher the recognized benefit will be. From the user's aspect technology acceptance depends on elements such as the simple adaption of technology and the perceived help of technology. These elements are parts of external motivation [5]. Besides these, technology acceptance depends on widespread motivation factors, such as the personal enjoyment. However, the supporting commitment is influenced largely by the external factors [3]. One of these can be the personal environment which influences the acceptance to a great extent. The contrary of this can occur also, as someone's environment can be influencing concerning the term and intensity of use [10].

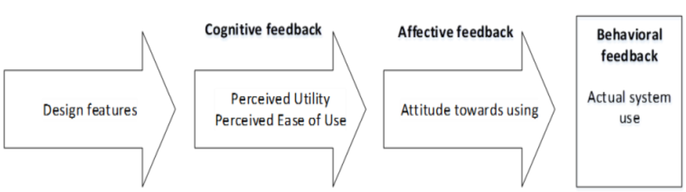

Fig. 3. Technology acceptance model [2].

A. Assumptions

The research is based on elements of the TAM model, so the aim was to examine links between these elements in the study as Fig. 4 indicates:

- Utility: shows how the user evaluates the usage of the system, if they concern it adequate.
- Use: shows how the user evaluates the complexity of the system.
- Experience: shows what impacts the usage of system generates in the user.
- Availability: shows to what extent the user is satisfied with the system concerning its accessibility.
- Attitude: shows the willingness of the user to accept and use the system in case of continual use.
- Intention: shows how the user relates to the future usage of the system.

Based on the model outlined and these elements, the relation between them can be supposed as follows:

- H1: There is a positive correlation between utility and attitude to the game.
- H2: There is a positive correlation between availability and attitude.
- H3: There is a positive correlation between experience and attitude.
- H4: There is a positive correlation between experience and intention for future usage.
- H5: There is a positive correlation between availability and attitude.
- H6: There is a positive correlation between availability and intention.
- H7: There is a positive correlation between use and utility.

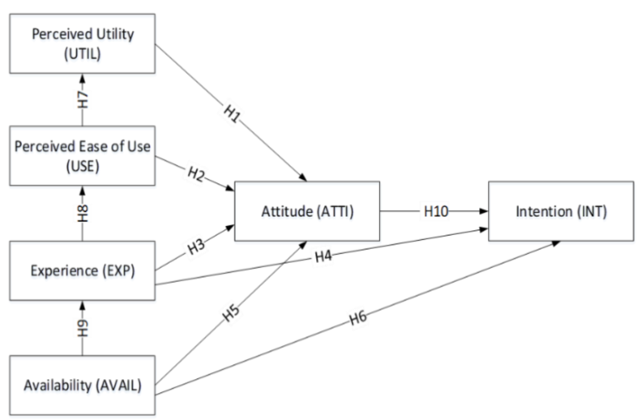

Fig. 4. Applied research model (based on Davis [2]).

H8: There is a positive correlation between experience and use.

H9: There is a positive correlation between availability and experience.

H10: There is a positive correlation between attitude and intention.

V. Research Process

Both primary and secondary research was carried out. In the course of the secondary research several publications from international databases were used. Based on these authentic and reliable data the primary research could be determined. After setting the aims and assumptions, a questionnaire was carried out as well. Students of The University of Miskolc and of The National University of Public Service participated in the survey. They could access to the questionnaire through the online Evasys system, on the webpage of evasys.uni-miskolc.hu. After reaching enough number of samples results were processed by the IBM SPSS Statistics 23 statistical software package. The questionnaire was formed based on the preliminary assumptions. Each question is dedicated to one hypothesis. In the survey only students using Kahoot! regularly could take part because the questions were connected with the application. Altogether, 86 samples were taken from non-IT students of The National University of Public Service and IT students of The University of Miskolc. The target group was the Z generation (shown coloured black in Fig. 5), the distribution of respondents by age is included in Fig. 5.

Fig. 6 shows the number of samples received from the university departments.

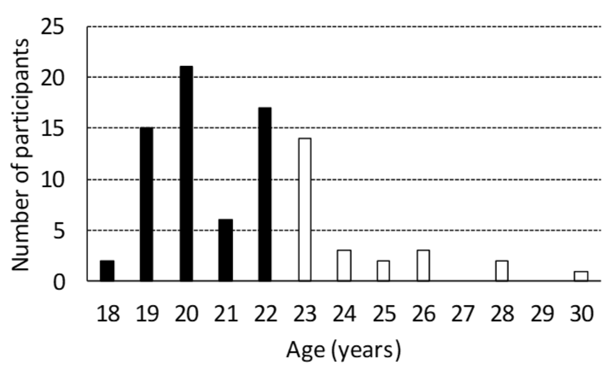

Fig. 5. Distribution of participation by age.

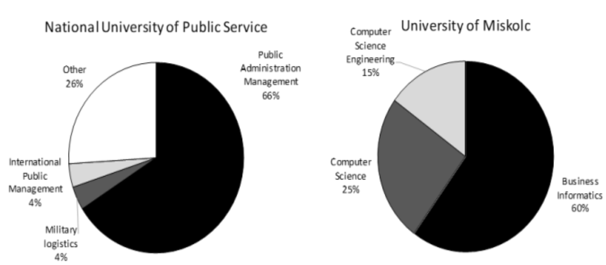

Fig. 6. Number of participants by university department.

Non-IT students of the National University of Public Service give the 59, 3% of the samples, and the IT students of the University of Miskolc give 40, 7%. Examining the samples in terms of the breakdown by gender, it can be observed that nearly 50-50 percent completed the questionnaire. 47% of the samples were taken from men, and 53% from women.

VI. Analytical Results Among University Students

A. Factor Analysis

After completing the descriptive statistical analysis of the data, the examination was continued with the principal component method which is a widely used method of factor extraction. First of all, in order to decide whether the data are appropriate for factor analysis it was essential to check their nature by KMO and Bartlett-test. The aim of the principal component analysis is to extract the maximum possible variance with successive factoring continuing until there is no further meaningful variance left. By the KMO (Kaiser-Meyer-Olkin) criterion we can decide whether our data are appropriate for factor analysis. The higher its value is, the more appropriate the variants are.

- KMO ⩾ 0,5 the data are suitable for factor analysis.
- KMO < 0,5 the data are not suitable for factor analysis.

Besides the appropriate value of the KMO, another criterion is to have correlation between the two variants which we can check with the Bartlett-test.

- H0: there is no correlation between the variants.
- H1: the variants are in correlation with each other.

After the examination of the test's results the H0 assumption could be ruled out both in case of IT and non-IT students because we can observe a correlation between the variants (p= 0.000, see Table 1), so they are suitable for factor analysis. The KMO value regarding the IT-students is 0.702 (see Table 1), while regarding the non-IT students it is 0.696 (see Table 1), so the variants are suitable for carrying out a factor analysis.

Having said that the variants are suitable for factor analysis, as a next step it was necessary to examine how many factors would be appropriate to be created. This appropriate number is 5 as it is included in the following two charts.

TABLE I. Results of the Kaiser-Meyer-Oklin (KMO) Test and Bartlett-Test Among IT and Non-IT Students

	IT students	**Non-IT students**
Kaiser-Meyer-Olkin (KMO) Test	0.702	0.696
Bartlett's Test significance	0.000	0.000

The Kaiser-criterion provides that only those factors which eigenvalue is not less than 1 have to be taken into account, because, in particular, it alleges that if the eigenvalue fall below 1, it carries negligible information, so it would become pointless to examine the data. When defining the factor number a further criterion is that the aggregated variant rate percentage must be 60%, in other words, the factors must contain at least 60% of the original information. If the 17 variants would be included into 5 factors it would contain 73.743% of the original information so we would obtain 12 variants with around 26.3% of the loss of information. These values can be easily calculated from the eigenvalues, as the explained variant percentage is the given eigenvalue's rate to all component numbers, and the cumulative percentage shows how many percentages of all variants can be explained when examining the given factor with the preceding factor's variant. The principal component analysis was carried out for non-IT students as well. It can be seen that both at the case of IT and non-IT students the principal component analysis created 5 groups, what's more it doesn't classify all of the questions to the group where the original expectations lay, however these 5 groups seem to be an insufficient number because the questions were divided into 6 categories before, so for the 5 factors are not suitable. Based on these we can assume that it's not practical to create more than 5 categories, so it was essential to check the original structure of 6 categories with the maximum likelihood estimation. The factor number shows the initial number of items, in other words the 17 factors. It appears that the slope of factors is steadily decreasing regarding at the examined categories. Searching for the "elbow point"– in other words the point where the slope breaks and start turn into horizontal–it's easy to see that the factor numbers can be maximized in 6 categories as well. The elbow detection technique entails that the factors which eigenvalues are below 1 can be important also in the course of an analysis. Having completed the previous statistical analyses, the variants could be divided into 6 categories – as mentioned above. So it became possible name the elements of the model as follows: As each element was asked in different ways the categorization simplified the following calculations.

B. Test-Retest Reliability

One of the most important questions when evaluating a survey is the reliability of the data. Most simply put, the aim of this test was to measure to what extent our survey makes precise calculation. The value of Cronbach's alpha is between 0 and 1, where the 1 shows the most reliability and the 0 the least reliability data. If the Cronbach's alpha > 0.7 the test can be considered reliable. Examining the test among IT students, this value is 0.798, while the same can be said about the test among non-IT students where the value of the alpha is 0.775 as the following table (Table 2) shows it. Both values proved to be reliable.

TABLE II. RESULTS OF THE RELIABILITY TESTING

Category	Cronbach's alpha	Number of questions
IT students	0.798	17
Non-IT students	0.775	17

C. Summary of the Results

Concerning the IT-students, we can observe a positive correlation at the level of 1% significance concerning H4 (Experience and Intention) and H9 (Availability and Experience). There is a positive correlation at the level of 5% significance in case of H10 (Attitude and Intention) and H7 (Easy Use and Utility), besides these the positive correlation regarding H8 (Experience and Easy Use) at the level of 10% significance is verified as well. The correlation values are indicated in Fig. 7.

Based on the results of non-IT students we can observe a positive correlation at the case of H4 (Experience and Intention) and H10 (Attitude and Intention) at the level of 1% significance. A positive correlation at the level of 5% significance can also be verified concerning the H1 (Utility and Attitude), H5 (Availability and Attitude) and H9 (Availability and Experience). Besides these, at the level of 10% significance positive correlation appears at H7 (Easy Use and Utility) and H6 (Availability and Intention). On the contrary, the H2 assumption (Easy Use and Attitude) was contradicted, because the two variables show negative correlation instead of the expected positive correlation. As a summary, four assumptions can be observed which were verified both at the case of IT and non-IT students. Based on the results, it can be said that the intention is always influenced by the attitude and experience which, at the same time, strongly depends on the availability of the application (here the Kahoot!). Both categorization shows that the easy use influences positively the perception of utility. The results are summarized in Table 3.

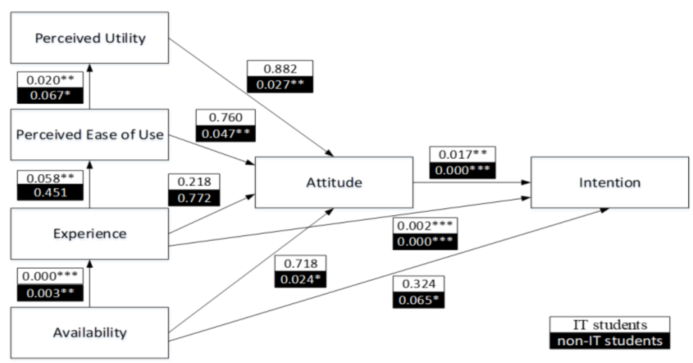

Fig. 7. Correlation between the elements of the model regarding IT students and non-IT students * ρ < 0.1, ** ρ < 0.05, *** ρ < 0.01).

TABLE III. SUMMARY OF THE RESULTS OF HYPOTHESIS TESTING

Hypothesis	**Verified**	
	IT students	**Non-IT students**
H1	no	yes
H2	no	no
H3	no	no
H4	yes	yes
H5	no	yes
H6	no	yes
H7	yes	yes
H8	yes	no
H9	yes	yes
H10	yes	yes

We can observe significant differences between the IT and non-IT students. The attitude of non-IT students are typically influenced by the utility and availability. There is a difference concerning the H6 hypothesis also because the future intention is influenced by the availability. Regarding the IT students, their attitude does not depend on the utility and availability, and their intention is not influenced by the availability. This can be explained by the fact that these students are much closer to the technologies of gamification, so due to their openness to new technologies no correlations could be identified between the availability of the application and their future intention to use the Kahoot!

VII. Summary

The use of gamification is still a sensitive subject of the Hungarian education system these days. A long time has passed by the time the lecturers established the point of view that instead of the traditional educational culture they involve a more modern method to pass on the knowledge and meanwhile the generation that needed this has grown up – based on the research results. In view of the low number of literatures found in this topic, during the work several publications could be found from foreign authors in different scientific databases. Based on these we brought back the concept of gamification and built it up enough to be used in the Hungarian higher education. Following the formation of the definition as well as separation of conceptual items different factors were determined which influence the road that leads to the success of gamification. On the other hand, the confirmation or refutation of hypothesis that were set up based on the TAM model became essential. The method consisted of the preparation of a questionnaire and then its statistical evaluation. 86 bachelor students answered the 20 questions that were asked in the EvaSys system. The first three complex questions of the survey were followed by 17 five degree Likert Scale questions. All the scalable questions were asking about one of our hypotheses. The conclusion is that the IT and non-IT students look at the use of gamification differently. Out of the 10 hypotheses only 5 were backed up with the IT students, meanwhile in the group of the non-IT students, 7 of our assumptions were verified. Based on the research results we can observe that students in certain IT classes didn't find the lectures immersive where the use of gamification was applied. The reason for this could be that part of their every day is formed by tools similar to some gamified lectures. This is backed up by the fact that most IT students used mobile applications to connect to the game. With respect to non-IT students gamification had clear success, however the assumption that the simple use of the game influences the approach to the game in a positive way, was refuted. The hypothesis that states there is a positive relationship between the simple use of experience and the detected was also refuted. We can come to the conclusion that the experience of the game does not influence the subjective quality of the application which determines how easy or hard it is to use. Based on the results summarized in the dissertation, gamification could propose a solution for the most serious problem of higher education, namely, the phenomenon that at the beginning of the semester students visit lectures and seminars actively but by the end of the semester – if there is no binding attendance list – the headcount decreases significantly.

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A Secure Mobile Learning Framework based on Cloud

Dr. Mohammad Al Shehri
CCIS, Majmaah University,
Al Majmaah
Kingdom of Saudi Arabia

***Abstract*—With the rising need for highly advanced and digital learning coupled with the growing penetration of smartphones has contributed to the growth of Mobile Learning. According to Ericsson's forecast, 80% of the world's population (6.4 billion people) will be Smartphone users by 2021. But the existing Mobile Learning Frameworks has some limitations that need to be addressed for mass adaptation, limitations include device compatibility and security. In this paper we propose a Secure Mobile Learning Framework (SMLF) based on TPM in the cloud. SMLF is supported by three layers Communication Module (CM) which helps in ensuring end to end security. In addition to this we propose a procedure for personalizing mobile learning applications of the student and instructors. We also propose a secure mobile learning protocol in SMLF framework. Proposed SMLF ensures mutual authentication of all the stakeholders, privacy of the message, integrity of the message, and anonymity of the student from the instructor and non-repudiation and is free from known attacks. Our proposed SMLF framework is successfully verified using BAN logic.**

Keywords—Trusted Platform Module (TPM); Communication Module (CM), anonymity; non-repudiation; personalized; BAN logic

I. Introduction

Mobile learning combines electronic content with learning support and services. Mobile learning systems requires specialized infrastructure but this infrastructure cannot be afforded by universities. Cloud provides a novel opportunity for these universities which is based on the distributed computing, parallel computing, grid computing and virtualization technologies. When adopting cloud technology in the realm of Mobile learning customers are not ready to deploy their applications in the cloud as security and data privacy are the main concerns in the cloud. Popularity of Mobile learning system should contain the following features L. Gouveia (1999) [8]:

a) Rich content and curriculum approved by experts.

b) Convenient & Flexible for all the stakeholders.

c) Continuous improvement.

d) Rich simulation with threaded discussion.

e) Should ensure Security and privacy in delivering.

Following are the requirements for mobile learning framework:

1) Authentication of Stakeholders: Student / Instructor / University identifications should ensure strong mutual authentication properties for all the stakeholders in the framework.

2) Privacy of the Message: Message privacy should be ensured among the messages exchanged among the stakeholders.

3) Integrity of the Message: Messages exchanged among the stakeholders should not be altered, so Message integrity property should be ensured for all the messages exchanged among the stakeholders.

4) Non-Repudiation: Non-repudiation property should be ensured in the framework to avoid stakeholders denying their involvement in the communication.

5) Anonymity of the student from the instructor: Anonymity of the student from the instructor should be ensured while submitting feedback for the instructor i.e. the real identity of the student should not be known to the instructor.

6) Unauthorized access to the stakeholder's credentials and private resource or information: No intruder or stakeholder in the framework should be able to access other stakeholder's credentials and private resource or information.

The rest of the paper is organized as follows: In Section 2 we present Related Work, in Section 3 we present our proposed mobile learning framework based on Cloud, in Section 4 we provide formal verification of SMLF protocol using BAN logic, Section 5 presents Comparative Analysis of our proposed framework with Related Works, and Section 6 concludes our work.

II. Related Work

Existing mobile learning solutions based on cloud such as [1]-[3] does not ensure non repudiation, mutual authentication, integrity properties. So this paper overcomes all the flaws of the existing solutions, by proposing a Secure Mobile Learning Model (SMLF) based on TPM in the cloud. SMLF is supported by three layers Communication Module (CM) and a novel procedure is proposed for personalizing mobile learning applications of the student and instructors. Proposed SMLF ensures authentication of all the stakeholders, privacy of the message, integrity of the message, and anonymity of the student from the instructor and non-repudiation and is free from known attacks.

III. Proposed Mobile Learning Framework

A. Proposed Four Layer Mobile Learning Model

In order to ensure success and to maintain the efficiency of the services, all the stakeholders must cooperate and stay open-minded to the development of new technologies, protocols and frameworks. We propose a four-layer mobile learning model involving stakeholders used to understand the functions and analyze the relationship among the stakeholders.

a) Mobile Learning Layer: The student, the University and the Instructor are the Stakeholders involved in this mobile learning layer. University acts as a Registration Authority (RA) by offering Mobile PKI services of registration to both students and instructors.

b) Communication Layer: A mobile learning framework is based on a wireless network, which is maintained by the mobile network operator. The mobile network operator is a part of communication layer and is responsible for carrying the data Over The Air (OTA).

c) Technology Layer: The software provider, Mobile device manufacturer, Secure Element (SE) manufacturer, Trusted Platform Module (TPM) manufacturer, and the Cloud provider are located in the Technology Provider layer. The software provider produces software components that connect different stakeholders in the Mobile Learning layer, while the Mobile device manufacturer provides the mobile devices to students and Instructors; the Secure Element (SE) manufacturer provides SE's to students and Instructors; the Trusted Platform Module (TPM) manufacturer provides TPM's to University, Cloud Provider, Mobile Network Operator (MNO) and Certifying Authority (CA) and finally Cloud Provider provides cloud services to mobile learning framework.

d) Supervision Layer: Certifying Authority (CA), Regulator (Department of Higher Education) and the Central Government are a part of this layer. Certifying Authority (CA) is responsible for issuing certificates, binds public keys and revokes certificates of all the stakeholders in the Mobile Learning framework. It issues X.509 version 3 and Short Lived Certificates (SLC) for all the stakeholders in the framework. It also acts as a Trusted Service Manager (TSM) which establishes an important link among Regulator, MNO and the Central Government. Department of Higher Education acts as a Regulator for all the universities in the country it frames and implements the policies for mobile learning framework from time to time. Regulator submits reports to the Central Government Time Stamping Authority (TSA).

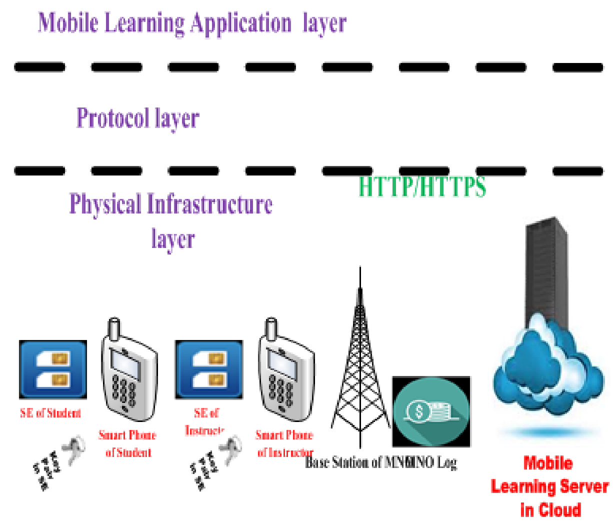

Fig. 1. Communication module of SMLF.

B. Proposed Communication Module

Student, Instructor and University are the three stakeholders involved in a normal mobile learning environment. Both Student and Instructor have a smart mobile phone with a Secure Element (SE) which connects with the cloud Over The Air (OTA) provided by MNO using wireless networks. Our proposed model is designed for the application layer so it focuses on the security of the business application layer in the three layer network model for mobile learning so we do not make any change in the protocol layer and physical infrastructure layer. Fig. 1 depicts the communication module of SMLF.

C. Proposed Procedure for Personalization

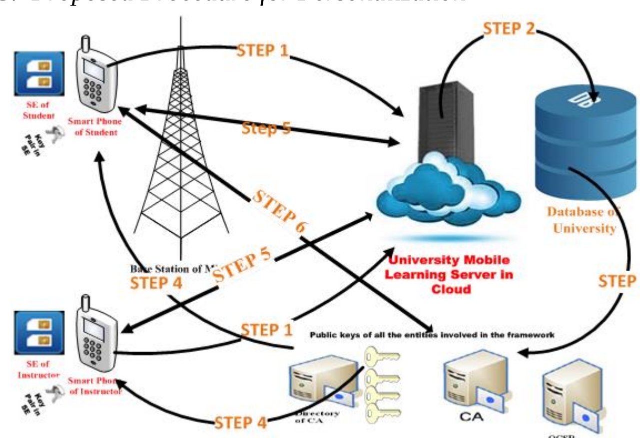

Fig. 2. Procedure for personalization of SMLF.

In this section we propose a procedure for personalization of SMLF, Fig. 2 depicts the procedure for personalization of SMLF.

1) Step 1: University acts as a Registration Authority (RA) for both Students and Instructors for issuing certificates. Certification Authority (CA) issues both X.509 and Short Lived Certificates (SLC) to all the stakeholders. CA issues Anonymous X.509 Certificates to all the students in order to ensure anonymity from instructors during the process of evaluating instructors (by the students). RA checks the certificate of the SEs of each and every student & instructor and maps the serial number and SE certificate to the user's national identity. All the stakeholders in the proposed mobile learning framework generate their credentials in the tamper resistant hardware such as Secure Element (Students & Instructors) and the Trusted Platform Module (TPM) of the University in the cloud.

2) Step 2: Trusted Platform Module (TPM) of the University in the cloud builds the database of the registered students and the instructors.

3) Step 3: All the students will be issued anonymous certificates in order to ensure anonymity of students during evaluating the instructor.

4) Step 4: Students and instructors will be asked to download mobile learning application which will be uploaded by the university in the cloud, before downloading the mobile learning application students and instructors will check the authenticity of the mobile learning application by downloading the certificate. If the checking is successful they accept the mobile learning application or report it to the university.

5) Step 5: Students and instructors will check the certificate of TPM of the university which is in the cloud. If the checks are successful they can start using Mobile learning application.

a) Students and instructors validates platform certificate of TPM of the university which is in the cloud using Certificate Validation Procedure given in (D.R. Stinson 2006) [7].

b) Validation of Students and instructors certificates is done by OCSP using Algorithm 1. $S \,\&\, I \rightarrow OCSP: U_{mla}$

c) /* C_{mla} is Mobile Learning Application Certificate */

d) Upon receiving positive response from OCSP, TPM installs Mobile Learning Application on the SE. /* this is the provisioning step */

e) University TPM personalizes Mobile Learning Application which is in the SE's of Students and instructors.

D. Proposed Secure Mobile Learning Protocol (SMLP)

$\boldsymbol{Step\ 1}: \boldsymbol{Ins} \ \rightarrow \boldsymbol{UMLS}: \{\boldsymbol{MS1}\}_{\boldsymbol{SYYKEY_{InsUMLS}}}$

$$\boldsymbol{MS1}: \{\boldsymbol{UN}, \boldsymbol{PW}, \boldsymbol{DS}(\boldsymbol{MS})_{\boldsymbol{Ins_{UMLS}}},$$

$$\boldsymbol{InsID}, \boldsymbol{MS}, \boldsymbol{SYYKEY_{InsULMS}}, \boldsymbol{T_{Ins}}, \boldsymbol{N_{Ins}}\}$$

Instructor sends $\{\boldsymbol{MS1}\}_{\boldsymbol{SYYKEY_{InsUMLS}}}$ to University Mobile Learning Server containing files to be uploaded (i.e. MS) and digitally signing the message $\boldsymbol{DS}(\boldsymbol{MS})_{\boldsymbol{Ins_{UMLS}}}$.

University Mobile Learning Server receives $\{\boldsymbol{MS1}\}_{\boldsymbol{SYYKEY_{InsUMLS}}}$ from the Instructor and verifies the files to be uploaded (i.e. MS) and verifies the digital signature of the message $\boldsymbol{DS}(\boldsymbol{MS})_{\boldsymbol{Ins_{UMLS}}}$, if the verification of digital signature is successful it uploads the (MS) message in the University Community Cloud.

$\boldsymbol{Step\ 2}: \boldsymbol{S} \ \rightarrow \boldsymbol{UMLS}: \{\boldsymbol{MS2}\ \}_{\boldsymbol{SYYKEY_{SUMLS}}}$

$\boldsymbol{MS2}: \{\boldsymbol{UN}, \boldsymbol{PW}, \boldsymbol{SID}, \boldsymbol{MS}, \boldsymbol{SYYKEY_{SULMS}}, \boldsymbol{T_S}, \boldsymbol{N_S}\}$

Student gets authenticated by the UMLS and is allowed to download the files uploaded by the instructor.

IV. Formal Verification of SRPF Protocol using BAN Logic

A security protocol is a communication protocol which exchanges encrypted messages by using cryptographic mechanisms [4] (Muhammad et al., 2006). Popular and carefully designed protocols were found out to have security breaches (Muhammad et al., 2006) [4]. We have analyzed the protocol using BAN logic [5] ((Abadi, M. et al. 1993) & [6] (Burrows,M. et al. 1990)).

A. Assumptions for the Analysis and Verification of the Proposed Protocol

1) Assumptions about keys and secrets:

'S' is a set of stakeholders containing {Ins, UMLS and S}. These assumptions gives a brief overview of public and private keys possessed by all the stakeholders. CA certifies all the certificates and knows all the public keys of the stakeholders (**AS1, AS2)**.

AS1. CA **believes** $(\forall S \in \{\text{Ins, UMLS and S}\} \overset{K_s}{\mapsto} S)$ Certification Authority CA believes that all the stakeholders have their own public keys to communicate.

AS2. $S \in \{\text{Ins, UMLS and S}\}$ S believes $\overset{K_{ca}}{\mapsto} CA)$. All the stakeholders in the framework knows the public key and certificate of the certification authority CA.

2) Assumptions about freshness:

Assumption **AS3** specifies freshness of quantities. For instance, if the Instructor Ins sees quantity ($\boldsymbol{N_{Ins}}$) in a message then the Instructor Ins can conclude that it is a replay message.

AS3. Ins believes freshness ($\boldsymbol{N_{Ins}}$, S believes freshness ($\boldsymbol{N_s}$).

Every stakeholder believes nonce generated by him/her is fresh

Assumption **AS4** is about validity time of certificates and timestamps which ensures timeliness.

AS4. TS_x & TS_y are the timestamps generated by the stakeholders X and Y ({Ins, UMLS, S and CA}) which ensures **timeliness** of the messages exchanged.

3) Assumptions about trust:

These assumptions gives a brief overview of trust level on each stakeholder.

AS5. $(\forall S, Q \in \{\text{Ins}, \text{UMLS}, \text{S and CA}\}$, S **believes** CA **controls** $\overset{K_{ca}}{\mapsto Q}$. Every stakeholder trusts the Certification Authority CA.

AS6. $\forall$ belief X, CA **believes** (W **controls** (P **believes** X)). The Certification Authority CA trusts the Student S that UICC or Secure Element (SE) (W) to relay Instructor Ins's beliefs.

B. Verification of our Proposed Protocol using BAN logic

$$\boldsymbol{Step\ 1: Ins \rightarrow UMLS: \{MS1\}_{SYYKEY_{InsUMLS}}}$$

$$\boldsymbol{MS1: \{UN, PW, DS(MS)_{Ins_{UMLS}},}$$

$$\boldsymbol{InsID, MS, SYYKEY_{InsULMS}, T_{Ins}, N_{Ins}\}}$$

UMLS decrypts the received $\{\boldsymbol{MS1}\}_{\boldsymbol{SYYKEY_{InsUMLS}}}$ from the assumptions AS1, AS2, AS5, AS6 & AS7.

UMLS believes $\{\boldsymbol{MS1}\}_{\boldsymbol{SYYKEY_{InsUMLS}}}$ statement (1)

UMLS verifies the public key of Ins (**AS7**) received from Ins which mainly includes [7] (D.R. Stinson 2006):

If the verification of certificate is successful then:

UMLS believes Ins said $\{\boldsymbol{MS1}\}_{\boldsymbol{SYYKEY_{InsUMLS}}}$ statement (2)

UMLS believes **fresh** T_{Ins} from **AS3** statement (3)

UMLS **believes fresh** N_{Ins} from **AS4** statement (4)

So from the statements 1 to 4

UMLS **believes** $\{\boldsymbol{MS1}\}_{\boldsymbol{SYYKEY_{InsUMLS}}}$

$$\boldsymbol{Step\ 2: S \rightarrow UMLS: \{MS2\}_{SYYKEY_{SUMLS}}}$$

$$\boldsymbol{MS2: \{UN, PW, SID, MS, SYYKEY_{SULMS}, T_S, N_S\}}$$

UMLS decrypts the received $\{\boldsymbol{MS2}\}_{\boldsymbol{SYYKEY_{SUMLS}}}$ from the assumptions AS1, AS2, AS5, AS6 & AS7 UMLS **believes** $\{\boldsymbol{MS2}\}_{\boldsymbol{SYYKEY_{SUMLS}}}$ statement (5)

UMLS verifies the public key of Ins (**AS7**) received from Ins which mainly includes [8] (D.R. Stinson 2006):

If the verification of certificate is successful then

UMLS believes S said $\{\boldsymbol{MS2}\}_{\boldsymbol{SYYKEY_{SUMLS}}}$ statement (6)

UMLS believes **fresh** T_S from **AS3** statement (7)

UMLS **believes fresh** T_S from **AS4** statement (8)

So from the statements 5 to 8:

UMLS believes $\{\boldsymbol{MS2}\}_{\boldsymbol{SYYKEY_{SUMLS}}}$

V. Security Analysis

a) End to End Security: Proposed SMLF ensures End to End Security, i.e. SMLF ensures authentication, integrity, confidentiality and non-repudiation properties.

b) Key pair generation and storage at the User side in secure element: UICC is used at student which is a secure element. UICC is used for generating and storing student's credentials.

c) Identity protection (Anonymity) of Student from Instructor: Student enrolls for anonymous identity with CA and University, both CA and University know the original identity of student. So the instructor will not be able to know the real identity of student.

d) Withstands well known attacks: Timestamps and nonce are included in the messages exchanged thereby avoiding replay attacks in our protocol. An intruder (In) cannot impersonate as student to CA and University because intruder (In) is not in possession of Student's private key, so impersonation attack is not possible in our protocol. Intruder (In) is not in possession of receiver's private key so man in the middle attack is not possible in our protocol.

VI. Comparative Analysis of the Proposed Solution with the Existing Solutions

In this section we present a comparative analysis of SMLF with related works. Table 1 depicts the comparative analysis of SMLF with related works.

TABLE I. Comparative Analysis of SMLF with Related Work

	NAAP [2]	**KAAP [3]**	**AUTHMAC_DH [1]**	**SMLF (Proposed)**
Message Privacy	No	No	No	Yes
Message Integrity	No	No	No	Yes
Non-Repudiation	No	No	No	Yes
Authentication	No	No	No	Yes
Message Privacy	No	No	No	Yes
Anonymity	No	No	No	Yes
Unauthorized access to the stakeholder's credentials and private resource	Yes	Yes	Yes	No
Proposed protocol is formally verified	No	No	No	Yes
MITM Attack	No	No	No	Yes
Replay Attack	No	No	No	Yes
Impersonation Attack	No	No	No	Yes

VII. Conclusions and Future Work

This paper proposes a Secure Mobile Learning Framework (SMLF) based on TPM in the cloud. SMLF ensures end to end security using Communication Module (CM), SMLF proposes a procedure for personalizing mobile learning applications of the student and instructors. We also propose a secure mobile learning protocol in SMLF framework. Proposed SMLF ensures mutual authentication of all the stakeholders, privacy of the message, integrity of the message, and anonymity of the student from the instructor and non-repudiation and is free from known attacks. Our proposed SMLF framework is successfully verified using BAN logic. Our future work is to verify the proposed mobile learning protocol using advanced formal tools (i.e. in simulation environment) such as AVISPA and Scyther tools in order to verify that it can withstand all the known attacks.

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Enhancing Gray Scale Images for Face Detection under Unstable Lighting Condition

Mathias A. ONABID
Department of Mathematics and Computer Science,
Faculty of Sciences, PO Box 67 Dschang
University of Dschang, Cameroon

DJIMELI TSAMENE Charly
Department of Mathematics and Computer Science,
Faculty of Sciences, PO Box 67 Dschang,
University of Dschang, Cameroon

***Abstract*—Facial expression plays a vital role in no verbal communication between human beings. The brain, in a quarter of second, can determine the state of mind and the behaviour of a person using different traits in a stable lighting environment. This is not the case in real applications such as online learning or driver monitoring system where lighting is not stable. It is therefore important to study and improve performance of some image enhancement techniques on face detection under varying lighting conditions in the spatial domain. The study is based on gray scale images. Nine gray scale standards based on colour space separating luminance to other colour components are used. The enhancement techniques compared are: the Global Histogram Equalisation (GHE), the Adaptive Histogram Equalisation (AHE) and Contrast Limited Adaptive Histogram Equalisation (CLAHE). Trials on the Labelled Face in the Wild (LFW) dataset using the Viola Jones Haar like features showed the CLAHE to outperform the GHE and AHE in face detection though the results appeared poor under low lighting condition. This motivated the need to stabilize lighting before applying Histogram Equalization techniques. The novelty in this research is that we have been able to apply the Gamma transform as a lighting stabiliser on the gray scale standard before enhancement. Comparing performance after lighting stabilisation showed AHE to be most appropriate for face detection, as it produced a detection rate of 99.31% and a relative high false positive rate (23.89 %).**

Keywords—Enhancement; AdaBoost; Haar like features; luma; peak signal to noise ratio (PSNR); Adaptive Histogram Equalisation (AHE); Contrast Limited Adaptive Histogram Equalisation (CLAHE); Global Histogram Equalisation (GHE); Gamma transform

I. Introduction

The face is one of the most important parts of the body, as it can be used to assess the state of mind, behaviour and even emotion of humans. Amongst the state of mind that can be assessed from facial expression are fatigue and somnolence. These aspects can be very useful when applied to driving control or online learning systems. The analysis of these aspects can only be possible after, face has been detected. Face detection under bright stable conditions possess no problem; but when lighting becomes unstable, the process of face detection becomes very challenging. This challenge is the motivation behind this research.

Lighting variation affects the perception of images and some of their features. The face in particular is highly affected since it has features which are light sensitive. It is therefore important to study image enhancement techniques and assess their impact on face detection using different features. This research is concerned with image enhancement in a spatial domain. Three enhancement techniques studied include, the Global Histogram equalisation (GHE), the Adaptive Histogram Equalisation (AHE) as developed by Pizer S M et al. [1] and the Contrast Limited Adaptive Histogram Equalisation (CLAHE) developed by Zuiderveld K. [2]. Most enhancement techniques are applied on gray scale images with different standards used to represent the images. To better assess their impact, nine standards which are mostly based on colour spaces which separate luminance to chrominance are used. In addition, many standards metrics used in assessing the impact of image enhancement use single images. This approach makes comparative study of dataset enhancement not feasible. In this research, an approach based on global peak signal to noise ratio (PSNR) is used.

A. Problem Statement

Most real time applications may require the detection of face in unstable or varying lighting conditions. This is a very crucial problem nowadays especially in the driving control and online learning systems where features of the face should be accurately detected in order to know the state of an individual. Commonly used enhancement techniques sometimes suffer from either over enhancement or under enhancement which oftentimes leads to reduced detection rate, due to the lighting variation. It is therefore important to stabilize lighting before applying enhancement.

B. General Objectives

The objective here is to attempt a solution to the problem of facial detection under lighting variation making use of some existing enhancement tools and then compare the impact of the enhancement on face detection. One approach in solving the unstable lighting problem is by pre-processing, which can be done by enhancing the image. The global Peak Signal to Noise Ratio (PSNR) is introduced to compare the effect of the enhancement methods on face detection.

Detection was done on the nearly frontal face and in a multi stage approach including: 1) conversion to gray scale, 2) apply an enhancement technique, 3) train the Haar like features using the Viola and Jones AdaBoost based method [3]. Assessment of the different approaches proposed was done using Labelled Face in the Wild (LFW) [4] dataset. To improve detection rate, the luma standard is used as a lighting stabiliser and Histogram based approach are later applied, as illustrated in Fig. 3.

II. Background and Related Work

Most of the facial detection systems start with image acquisition, followed by the extraction of the facial area before further processing. Given an arbitrary image, the goal of face detection is to determine whether or not there is any face in the image and if present, returns the location of each face found in the image. The challenges associated with image detection include: Pose, Presence or absence of structural component, Facial expression, Occlusion, Image orientation and Imaging condition.

In order to detect any face, it is necessary to choose the proper way to represent data so that it can increase the accuracy of the classification method. Song F et al. [5] stated that, given a data patch, several visual feature sets can be extracted from it. Each feature set is simply a transformation of a set of neighbouring raw pixel values, designed to be invariant to certain changes. Since no single feature descriptor will satisfy all the needs, selections for practice are mostly application-driven and the factors that need to be taken into account include: 1) the invariance properties it provides (e.g., invariance to lighting changes or to variations in scale, orientation, and other affine transformations); 2) the information encoded and the discriminability preserved; 3) the computational efficiency.

Hemalatha G and Sumathi C P. [6] proposed a classification of face detection techniques based on Knowledge based method, Facial invariant method, Template matching method and Appearance based method. A more simple but expressive classification approach has been given by Ce Zhan [7] where classification is on Knowledge based method and learning based method. In this, he states that the knowledge-based method attempts to depict our prior knowledge about the face pattern with some explicit rules, such as the intensity of faces, elliptic face contour, and equilateral triangle relation between eyes and mouth. Learning based method in the other hand, tries to model patterns with distribution or discriminant functions under a probabilistic framework. Some of these methodologies include Support Vector Machines (SVM), Artificial Neural Networks (ANN) and Bayesian-rule methods.

This learning based method is very effective with complex cases compared to knowledge based approach, however its drawback is that powerful computations are required due to learning model and large training data set with great variations. Recently this approach obtained better successes as the use of boosting has proven to be effective in reducing computational time. This is seen in Viola and Jones [3] where a real-time approach based on AdaBoost, was proposed. This has been the breakthrough of learning-based methodology.

A. Viola and Jones Face Detection Algorithm [3]

In Viola and Jones [3] approach, face detection is based on:

1) Feature representation: Haar like feature

Features used are reminiscent of Haar basis functions. Each feature is composed of a number of “black” and “white” rectangles joined together. After the approach of Viola and Jones succeeded, an extended set of Haar-like features were added to the basic feature set by Rainer Lienhart and Jochen Maydt [8]. This set contains more than 15 kinds of Haar like feature types.

2) Boosting

They used boosting as features classifier and selector, which converts a weak classifier to a strong one by combining a number N of weak classifier of $h_j(X)$ to form the strong classifier $H(X)$ using the formula:

$$H(X) = \sum_{j=1}^{N} w_j h_j(X) \tag{1}$$

Zhou Z H et al [9], proposed three modifications to the original Adaboost algorithm. These include: Gentle-, Logit-, and Real. The aim of boosting is to improve the classification performance while reducing the training duration.

3) Attentional Cascade

Viola and Jones [3] defines a weak classifier $w(x)$ with features f , parity p which indicates the direction of the inequality sign and some threshold σ as follows:

$$w(x) = \begin{cases} 1 \text{ if } pf(x) < p\sigma \\ 0 \quad \text{otherwise} \end{cases} \tag{2}$$

Where, x is a sub-window of an image. This means that if the value of some feature exceeds some threshold, which has to be learned, the image is classified as positive.

They proposed the selection of a subset of relevant features which are sufficiently informative to model a face. The idea is that a very small subset of features can be combined to form an effective classifier. Adaboost classifier has been found to be appropriate for that purpose. Adaboost searches for a small number of good features classifier and then constructs a strong classifier as a linear combination of weighted simple weak classifiers as shown in Fig. 1.

In Fig.1, the structure reflects the fact that within any single image the majority of sub-windows are negative. As such, the cascade attempts to reject as many negatives as possible at the earliest stage.

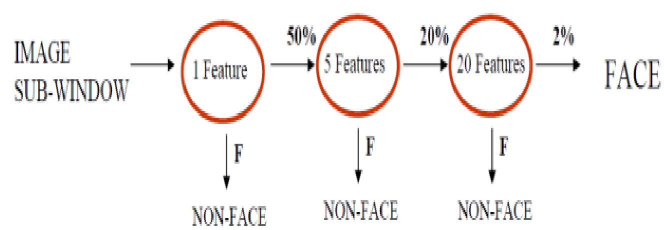

Fig. 1. Cascade structure of Duncan S. and Velthuis T [10].

Duncan S. and Velthuis T. [10] states that for each sub-window, the order of complexity is $O(FS_f)$, where, F is the number of Haar-like features used by the cascade and S_f is the number of pixels contained by each feature. Using the cascade most sub-windows can quickly be discarded and only True Positive and False Positives will run the whole cascade. The total number of operations is order $O(NFS_f)$, where N is the total amount of sub-windows and FS_f, is a function of the image size and number of scales included in the search.

B. Image Representation in Various Colour Space

Generally, a colour space can be seen as a mathematical representation of a set of colours of which the three most popular colour models are Red Green Blue (RGB) used in computer graphics; Luminance, Inphase Quadrature (YIQ), YUV, or Luminance Chominance blue and Chrominance red (YCbCr) used in video systems as stated by Huanzhao Zeng [11]. Other known colour models include the Hue Saturation Intensity (HSI) and Hue Saturation Value (HSV) which could be used to simplify programming, processing, and end-user manipulation. For colour adjustment, luminance is the major concern when compared to Saturation and Hue.

1) Numerical analysis of colour

Huanzhao Zeng [11] states that a 3-dimensional Euclidean space can better represent the human perception of colour since based on the cone analysis three numbers can be used to represent the three types of cones. Author [11] further states that each wavelength λ stimulates each of the three types of cone cells to a known extent, these extents may be represented by three functions, s(λ), m(λ), l(λ) corresponding to the response of the S, M, and L cone cells, respectively. Since a beam of light can be composed of many different wavelengths, to determine the extent to which a physical light C(λ) stimulates each cone cell, we must calculate the integral (with respect to λ) over the interval [λmin , λmax] as follows:

$$S = \int_{\lambda_{\min}}^{\lambda_{\max}} C(\lambda).\, s(\lambda) d\lambda \quad (3)$$

$$M = \int_{\lambda_{\min}}^{\lambda_{\max}} C(\lambda).\, m(\lambda) d\lambda \quad (4)$$

$$L = \int_{\lambda_{\min}}^{\lambda_{\max}} C(\lambda).\, l(\lambda) d\lambda \quad (5)$$

In order to simplify the problem, the CIE (Commission Internationale de l'Eclairage) defined a standard colour space CIEXYZ which uses a set of tristimulus values called X, Y, and Z. These X, Y, and Z values are used instead of the tristimulus values the S, M, and L responses of the human eye. In that regard the CIE has defined a set of three colour-matching functions, called $x(\acute{\lambda}), y(\acute{\lambda})$ and $z(\acute{\lambda})$, which can be thought of as the spectral sensitivity curves of three linear light detectors that yield the CIEXYZ tristimulus values X, Y, and Z as described in Huanzhao Zeng [11]. Furthermore, Huanzhao Zeng [11] states that some variations of CIEXYZ were latter deduce from the standard including CIELAB and CIELUV.

*2) CIE uniform colour spaces (CIE L*a*b* , CIE L*u*v)*

Huanzhao Zeng [11] also states that to improve the visual uniformity of colour, several colour spaces have been used, the most common being the CIELAB colour space which is illustrated as follow:

$$L^* = 116 f\left(\frac{Y}{Y_n}\right) - 16 \quad (6)$$

$$a^* = 500\left[f\left(\frac{X}{X_n}\right) - f\left(\frac{Y}{Y_n}\right)\right] \quad (7)$$

$$b^* = 200\left[f\left(\frac{Y}{Y_n}\right) - f\left(\frac{Z}{Z_n}\right)\right] \quad (8)$$

Where,

$$f(t) = \begin{cases} t^{\frac{1}{3}} & \text{for } t > (\frac{24}{116}) \\ \left(\frac{841}{108}\right) t + \frac{16}{116} & \text{otherwise} \end{cases} \quad (9)$$

XYZ are the tristimulus values of a colour and X_n Y_n Z_n are the tristimulus values of the reference white being used. L^*, represents the lightness, a^* and b^* represent the chroma coordinates. The chroma is computed as $c = \sqrt{a^2 + b^2}$. An implementation of CIELAB is given by opencv whereby.

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \begin{pmatrix} 0.412453 & 0.357580 & 0.180423 \\ 0.212671 & 0.715160 & 0.072169 \\ 0.019334 & 0.119193 & 0.950227 \end{pmatrix} \text{ and}$$

$$L = \begin{cases} \frac{255}{100}\left(116 Y^{\frac{1}{3}}\right) & \text{for } Y > 0.008856 \\ \frac{255}{100}(903.3Y) & \text{for } Y \le 0.008856 \end{cases} \quad (10)$$

$$a *= 500[f(X) - f(Y)] + \Delta + 128 \quad (11)$$

$$b^* = 200[f(Y) - f(Z)] + \Delta + 128 \quad (12)$$

Where, Δ takes 128 value for 8 bits value and 0 for floating point. The function f is defined by:

$$f(t) = \begin{cases} t^{\frac{1}{3}} & \text{for } Y > 0.008856 \\ 7.787t + \frac{16}{116} & \text{for } Y \le 0.008856 \end{cases} \quad (13)$$

3) HSV/ HSL

Hue-Saturation-Value (HSV) space is also a popular colour space as it is based on human colour perception. Similarly, HSI (I-Intensity) and HSL (L-Lightness) colour spaces are derived from HSV. The intensity, value and lightness are related to the colour luminance. Acharya Tand Ray A [12] stated that HSV provides absolute brightness information. Opencv proposed an implementation of HSV where the value is given as the maximum of the R,G,B component of the pixel. That is,

$$V = \max(R, G, B) \quad (14)$$

HSL is another Hue based colour space where the lightness value is the mean of the minimum and maximum RGB values given as

$$L = \frac{V + \min(R,G,B)}{2} \quad (15)$$

C. Gray Scale Conversion of Luminance Components

Luminance is the weighted sum of the RGB components of a colour image. The luminances are obtained using three defined constants C_R, C_G, and C_B define by (16) given as:

$$Y = C_R \times R + C_G \times G + C_B \times B \quad (16)$$

The C_R, C_G, and C_B values are given according to the International Telecommunication Union (ITU) standards illustrated in Table 1, also $C_R + C_G + C_B = 1$.

The ITU-R BT.601 [13] conversion rule is the widely used rule to convert the luminance components of the YIQ, YUV and YcbCr systems. In Table 2, a summary of some luminance based gray scale standard is given. R', G' and B' are obtain respectively from R, G and B using Gamma transform.

D. Enhancement Techniques

Bedi S.S. and Rati Khandelwal [16] explained that the aim of enhancing is to improve the visual appearance of the image for future automated processing, such as analysis, detection, segmentation and recognition and Anish Kumar Vishwakarma [17] did classified Image enhancement techniques into two broad categories: Spatial based domain image enhancement and Frequency based domain image enhancement. Author [16] sub classified spatial based category into point processing operation and spatial filter operations. In this paper, focus is on image enhancement technique in a spatial domain, especially histogram equalization based technique as described below.

1) The histogram equalization

Gonzalez R C and Woods R E [18] explains that the idea behind histogram equalization is to enhance an image such that its histogram will be flat, in other words a transformation of the form $Y = T(X)$ could be created to produce a new image Y with a flat histogram. That is for a digital gray image $X = \{x\}$ with gray levels in the range [0, L −1], $Y = \{y\}$ the enhance image and let n_i be the number of occurrences of gray level *i*. Then the Probability Distribution Function (PDF) of the image which is the probability of an occurrence of a pixel of level *i* in the image can be computed as:

$$p_x(i) = p(x = i) = \frac{n_i}{n} \quad 0 \leq i < L \tag{17}$$

TABLE I. ITU STANDARD TO REPRESENT GRAY SCALE IMAGES

ITU Standard	C_R	C_G	C_B
ITU-R BT.601 conversion[13]	0.299	0.587	0.114
ITU-R BT.709 conversion[14]	0.2126	0.7152	0.0722
ITU-R BT.2020 conversion[15]	0.2627	0.678	0.0593

TABLE II. GRAY SCALE STANDARD USED

Standard	Gray value
Luminance1	$\mathbf{0.299 \times R + 0.587 \times R + 0.114 \times B}$
Luminance2	$\mathbf{0.2126 \times R + 0.7152 \times G + 0.0722 \times B}$
Luminance3	$\mathbf{0.2627 \times R + 0.678 \times G + 0.0593 \times B}$
Luma1	$\mathbf{0.299 \times R' + 0.587 \times G' + 0.114 \times B'}$
Luma2	$\mathbf{0.2126 \times R' + 0.7152 \times G' + 0.0722 \times B'}$
Luma3	$\mathbf{0.2627 \times R' + 0.678 \times G' + 0.0593 \times B'}$
Luminance HSV	$\mathbf{Max(R, G, B)}$
Luminance HSL	$\mathbf{\frac{Max(R, G, B) + min(R, G, B)}{2}}$
Luminance CIELAB/CIELUV	Equation $(\mathbf{2.10})$

The Cumulative Distribution Function (CDF) can be computed as follows:

$$\mathrm{cdf}_x(i) = \sum_{j=0}^{i} p_x(j) \tag{18}$$

And to create the mapping transformation one has to linearize the CDF across the value range, i.e.

$$\mathrm{cdf}_y = iK \tag{19}$$

The histogram equalized image Y will be defined by,

$$Y(i, j) = (L - 1) \sum_{n=0}^{X(i,j)} p(x = n) \tag{20}$$

The motivation for this transformation comes from thinking of the intensities of the continuous random variables X, Y on [0, L – 1] with Y defined by

$$Y = T(X) = (L - 1) \int_0^X p_X(x)dx \tag{21}$$

T is the cumulative distributive function of X multiplied by (L – 1). Assume for simplicity that T is differentiable and invertible. It can then be shown that Y define by T(X) is uniformly distributed on [0, L – 1], namely,

$$p_Y(y) = \frac{1}{L-1} \tag{22}$$

If the histogram of any image has many peaks and valleys, it will have peaks and valleys after equalization but the peaks and valleys will be shifted. This technique improves contrast but the goal of histogram equalization is to obtain a uniform histogram. Anish Kumar Vishwakarma [17] defined three main types of Histogram Equalization, namely, Global Histogram Equalization (GHE), Adaptive Histogram Equalization (AHE) and Block-based Histogram Equalization (BHE).

- *Global Histogram Equalization (GHE)*:

According by Agaian et al. [19], the GHE attempts to alter the spatial histogram of an image to closely match a uniform distribution. It uses the same transformation derived from the image histogram to transform all pixels. This approach works well when the distribution of pixel values is similar throughout the image. However, when the image contains regions that are significantly lighter or darker than most of the image, the contrast in those regions will not be sufficiently enhanced. The drawbacks of GHE as identified by Bedi and Rati [16] include:

1) Problem of being poorly suited for retaining local detail due to its global treatment of the image

2) Over enhancing the image, resulting in an undesired loss of visual data, of quality and of intensity scale.

In fact, global histogram modification treats all regions of the image equally and, thus, often yields poor local performance in terms of detail preservation. This motivated the introduction of AHE.

- *Adaptive Histogram Equalization (AHE)*:

In an attempt to treat the aspect of details preservations, the AHE was built. The idea behind this technique as described by Pizer S M et al. [1] is to transform each pixel with a transformation function derived from a neighbourhood region. That is each pixel is transformed based on the histogram of a square surrounding it but the derivation of the transformation functions from the histograms is exactly the same as for ordinary histogram equalization.

Arun R et al. [20] explains that though this method produces better result, it has the shortfall of over amplifying noise in relatively homogeneous regions of an image. Such that noise in dark regions could be over amplified until it becomes visible. The result is that often times, Block effect is observed in the output after sub-image processing. Thus the Contrast Limit AHE of Zuiderveld K [2] was developed as a means to address the problem to some extent.

- *Contrast Limited AHE (CLAHE)*:

Zuiderveld K [2] describes the CLAHE technique, to operate on small regions in the image, called *tiles*, rather than the entire image, and that each tile's contrast is enhanced, so that the histogram of the output region approximately matches the histogram specified by the CDF. The value, at which the histogram is clipped, known as clip limit, depends on the normalization of the histogram and hence on the size of the neighbourhood region. The part of the histogram that exceeds the clip limit is not discarded rather it is redistribute equally among all histogram bins as illustrated in Fig. 2.

Fig. 2(a) shows a CDF with a slope that can lead to amplification of tiles, so it is important to limit the slope and hence the of the transformation function. The redistribution of Fig. 2(b) will push some bins over the clip limit again resulting in an effective clip limit that is larger than the prescribed limit. The neighbouring tiles are then combined using bilinear interpolation to eliminate artificially induced boundaries. The contrast, especially in homogeneous areas, can be limited to avoid amplifying any noise that might be present in the image.

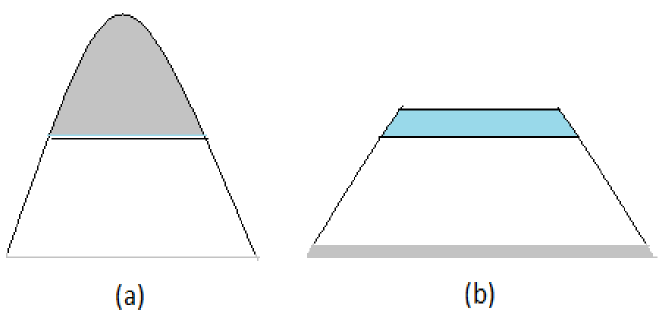

Fig. 2. Illustration of the clip limit effect.

E. Related Work

Many authors have tried to assess the performance of image enhancing techniques accuracy face detection. These include:

Li Tao [21], who proposed image enhancement technique to improve the visual quality of digital images that exhibit dark shadows due to the limited dynamic ranges of imaging and display devices which are incapable of handling high dynamic range scenes. The proposed technique processes images in two separate steps:

1) Dynamic range compression is able to enhance the luminance in dark shadows while keeping the overall tonality consistent with that of the input image, and

2) Local contrast enhancement which uses a neighbourhood dependent local contrast enhancement method to enhance images following the dynamic range compression.

To detect face they used a convolution face finder which is based on Convolutional Neural Network (CNN). These were tested on sample face images containing one up-right frontal human face in each image from the Phillips P J et al. [22] FRGC dataset. A comparative study showed their method to perform better that the GHE method.

Venkatesan M.E and Srinivasa Rao [23] proposed a Hybrid algorithm to detect faces using Ant Colony Optimization (ACO) and Genetic programming algorithms. The enhancement method used is the Histogram Equalization. The Ant colony is used to search the face area while the genetic programming is used to select and generate chromosome features used by ant colony. Though no real database was used for performance comparison, the author acknowledges that the method is time consuming compared to Viola and Jones [3].

Deepak Ghimire and Joonwhoan Lee [24], proposed a method to detect human faces in colour images in which three steps were involved:

1) Colour image enhancement is performed using a nonlinear transfer function that is based on a local approach.

2) Two separate processes are carried out and this included the luminance enhancement in which dynamic range compression is performed on the V channel image using a nonlinear transfer function, and a contrast enhancement in which each pixel in the image is further enhanced to adjust the image contrast, depending upon the centre pixel and its neighbourhood.

3) Finally, the original H and S component images and enhanced V component image are converted back to the RGB.

The method was tested on an unknown database and produces a detection rate of 85.96%.

Table 3 presents a global comparison of these different enhancement approaches, their features descriptor, data classification and some of the associated drawbacks. The belief is that if light is stabilized before applying these techniques, the detection accuracy will improve. This is the main concern of this research.

TABLE III. COMPARISON OF RELATED WORK

Authors	Enhancement techniques	Descriptor	Classifier	Drawback
Viola Jones (2001)	Global Histogram equalization	Haar-like features	AdaBoost	Over enhancement
Li Tao (2006)	Dynamic range compression and local contrast enhancement	Feature map	Convolutional Neural network (CNN)	Two step processing and uses CNN which takes much time in training.
Venkatesan M.E. (2010)	Global Histogram equalization	Chromosome based features	Ant Colony Optimisation and Genetic Algorithm	Time consuming due to OCA classifier
Deepak Ghimire (2013)	Luminance + contrast enhancement in HSV	Skin Colour segmentation and Edges	Linear classifier	Enhancement done in more than one step with more than one colour.

III. METHODOLOGY

Phillips P J et al. [22] made it clear that the conventional methods like histogram equalization and Gamma transform generally have very limited performance due to the global processing scheme especially when lighting varies. It is therefore necessary to improve and stabilise lighting condition before enhancing. This is the main concern of this research as outlined below.

A. System Overview

In our work, Gamma transform is first applied to stabilize lighting, before other enhancing techniques are applied.

Fig. 3 gives a global view of our system. The Gamma transform is first apply to the RGB image to stabilise lighting variation; AHE is applied to enhanced the global system, though it still produces unnatural image it has the advantage of better highlighting facial features.

For implementation we are going to use, opencv platform with C++ language, the CLAHE implementation is the one given by opencv. The clip limit value for CLAHE is 0.02 and the Gamma transform coefficient of luma is 0.2.

We have train haar like classifier using the various gray scale standards.

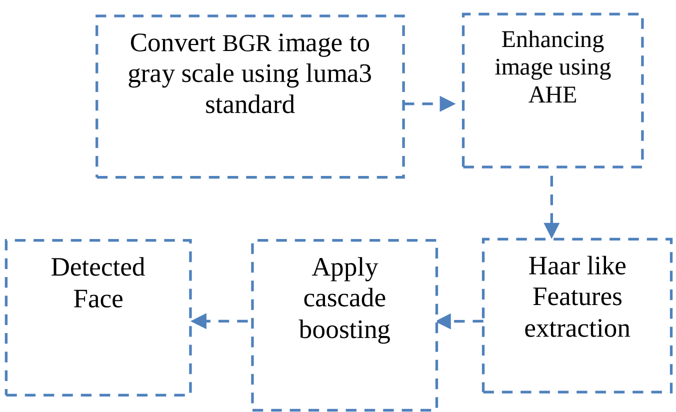

Fig. 3. Luma based face detection system.

B. Training Stages

For training we used the following stages as describe by author [3] and implemented in the Opencv:

STEP 1: Collecting Image Database

We collected about 3000 positive images, that is, images containing at least one face from the internet and about 1000 negative images that is images without a face. Each set of images is placed in a folder.

STEP 2: Convert images to gray scale and apply enhancement

Positive and negative images were converted to gray scale using the 8 standards described in Section 2.3. After which three enhancements techniques are applied to these gray scale standards in separated patches.

STEP 3: Crop and Mark Positive Images

We need to create a data vector file that contains the names of positive images as well as the location of the objects in each image. The format of the vector file is of the form

(x and y represent the top left vertex):

image_path number_of_face x-coord y-coord width length

STEP 4: Creating a vector of positive images

In this stage we create a vector file using a .vec format, which is a data file containing face location.

STEP 5: Haar-Training and XML file

For training, the following characteristics: 20 stages, Haar like features and Gabor Adaptive Boosting are used. At the end of the training stage, a .XML file is obtained.

A comparison of this method is given in the next section.

C. Performance Criteria

A study will be done to compare image quality and face detection rate. For image quality two metrics will be used which are all based on:

- *MSE (Mean Square Error)*:

It is the cumulative squared error between the enhanced and the input images. Sonam Bharal [25] used it to assess image quality of some enhancement techniques. It is defined as follows:

$$\mathrm{MSE} = \frac{1}{\mathrm{MN}} \sum_{\mathrm{m}=1}^{\mathrm{M}} \sum_{\mathrm{n}=1}^{\mathrm{N}} (\mathrm{I}_1(\mathrm{m},\mathrm{n}) - \mathrm{I}_2(\mathrm{m},\mathrm{n}))^2 \qquad (23)$$

Where, I_1 and I_2 denote the original image and the improved image, respectively. The size of the input and output pictures should be same. If MSE is very large then it means that the quality of the image is very low.

- *Peak Signal to Noise Ratio (PSNR)*:

PSNR defines the ratio between an original image and a new one obtained by introducing error during compression. The PSNR can be obtained using the following formula:

$$\mathrm{PSNR} = 10 \log_{10} \frac{(2^{\mathrm{b}}-1)}{\mathrm{MSE}} \qquad (24)$$

Where, b is the number of bits per pixel (bpp) of the original image and MSE is the mean-square-error. Hitam et al. [26] showed that PSNR with high value indicates better quality of the image with less noise. They also declared that good methods are those that result to lower MSE and higher PSNR values.

To assess the relation between image quality and face detection, *Algorithm 1* is used; the algorithm uses the standard deviation of each image PSNR and compute a global PSNR of the image folder. Local PSNR is obtained using (24).

The next thing to asses is face detection, different metrics are used for that purpose. In this article we will evaluate the True Positive Rate (TPR) and the False Positive Rate (FPR). The evaluation uses the following matching metrics as defined by Richard Szeliski [27]:

True Positives (TP): Number of objects correct detected.

False Negatives (FN): Object that were not correctly detected, in other word matches identified as negative while they are supposed to be positive.

False Positives (FP): Proposed matches that are incorrect, in other word matches considered as positive while they are really negative.

True Negatives (TN): Non-matches that were correctly rejected. Based on the previous definition, we can define these numbers in terms of unit rates as follows:

Hit rate, sensitivity or True Positive Rate (TPR):

$$TPR = \frac{TP}{TP+FN} = \frac{TP}{P} \qquad (25)$$

Miss rate or False Positive Rate (FPR):

$$FPR = \frac{FP}{FP+TN} = \frac{FP}{N} \qquad (26)$$

Algorithm 1: Compute Image Global PSNR

Input: image folder

Output: global PSNR

1. *Initialization: global PSNR =0*
2. *For each image ∈ images folder*
   - *Read the image and Convert the RGB to gray scale image called **ImRef***
   - *apply an enhancement technique to **ImRef** to obtain **ImEnh***
   - *Process the **localPSNR** using **ImRef** and **ImEnh***
3. *endFor*
4. *Compute the standard deviation of all the **localPSNR** found in the folder.(**global PSNR=standard deviation of all the localPSNR)***
5. *return **global PSNR**,*

IV. Results and Discussion

A. Experiments and Results

To carry out experiments the Labelled Face in the Wild (LFW) [4] database which shows poor image quality and great appearance datasets is used.

Using the set of 3000 positive images and 1000 negative images, data were trained following the stages given in the section *B.* The output of the training process gave a set of 48 .XML classifiers, which were later used for experiment.

TABLE IV. Comparison of Enhancement Technique with the Use of PSNR

Gray scale standard	**Enhancement Method**	**LFW Dataset**		
		TPR	FPR	PSNR
Luminance1	Not Enhanced	98.26	24.13	
	AHE	95.35	16.20	10.25
	CLAHE	**98.91**	**21.76**	**29.91**
	GHE	97.93	23.82	17.35
Luminance2	Not Enhanced	98.35	20.12	
	AHE	96.90	18.53	10.21
	CLAHE	**98.49**	**17.85**	**29.84**
	GHE	97.86	20.36	17.26
Luminance3	Not Enhanced	98.52	28.26	
	AHE	96.28	16.32	10.33
	CLAHE	**98.80**	**23.30**	**29.93**
	GHE	97.78	24.28	17.36
Luminance HSL	Not Enhanced	98.43	22.39	
	AHE	96.46	14.72	10.31
	CLAHE	**98.92**	**19.26**	**29.78**
	GHE	98.39	22.74	17.22
Luminance CIELAB/ CIELUV	Not Enhanced	98.31	29.92	
	AHE	96.79	21.79	10.32
	CLAHE	**98.79**	**21.60**	**30.14**
	GHE	98.15	20.46	17.96
Luminance HSV	Not Enhanced	98.27	29.38	
	AHE	94.27	19.03	10.60
	CLAHE	**98.51**	**24.74**	**31.54**
	GHE	97.84	26.47	19.01

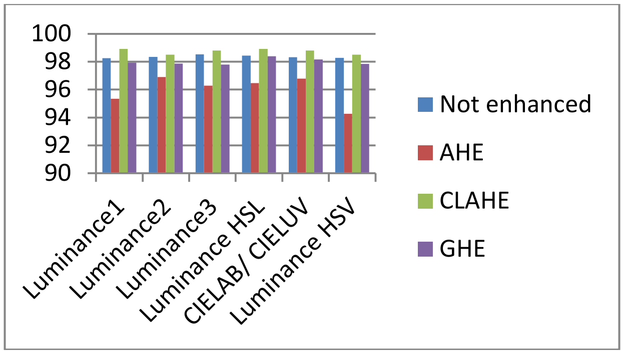

Fig. 4. Comparison of enhancement techniques for face detection on LFW dataset.

To assess the result of the classifiers, LFW dataset is used and applied in each classifier. The result is given in Table 4 and Fig. 4. From the experiments carried out across the various gray scale standards, it was found that the higher the PSNR, the higher the accuracy of the detection method, using Haar like features.

Observation showed the CLAHE outperform the other enhancement techniques at face detection as seen in Fig. 4. The experiments also showed CLAHE to produce greater PSNR and higher detection rate. Yet for over lighted or under lighted condition it produces very low result as illustrated in Table 5.

Table 4 shows that CLAHE outperform in TPR, both AHE and GHE, also the PSNR of CLAHE is greater than the one used by AHE.

To stabilize lighting before enhancing we proposed a technique based on luma as illustrated in Fig. 3. In this technique, Gamma transform is first applied to the image before enhancing using the equalization techniques. The results showed that AHE applied on luminance3 standard performed better. Though it produced unnatural image it better highlighted the facial features than the other method.

B. Discussion

To justify the approach, other techniques are used to compare performance. Experimental trials showed the proposed method, based on Gamma transform and adaptive histogram equalisation performed better than the other techniques. The enhancement method used is a mixture of global enhancement (Gamma Transform) and local enhancement (AHE).

The global enhancement stabilised the light while the local enhancement let the system to easily discriminate the main features, that eyes, mouth, and nose can be easily extracted using rectangle features. Also, the AHE by performing a local enhancement with no clip limit makes the image to appear, though unnatural but with visible features.

The PSNR result shows CLAHE produces better quality image than any other image, yet the quality of image has little impact in very low lighting condition and feature based detection method as seen in Fig. 5. That is why, though the proposed method produces a very low global PNSR (2.41dB) it has a better detection. This is due to the unnatural image given by AHE, which in contrary has better result (99.31% of TPR).

TABLE V. COMPARISON OF LUMA STANDARD

Gray scale standard	**Enhancement Method**	**LFW Dataset**		
		TPR	**FPR**	**PSNR**
Luma1	Not Enhanced	0	100	
	AHE	98.77	21.62	2.46
	CLAHE	0	100	0
	GHE	97.52	19.22	3.93
Luma2	Not Enhanced	0	100	
	AHE	99.16	25.40	2.41
	CLAHE	0	100	0
	GHE	97.78	27.16	3.95
Luma3	Not Enhanced	0	100	
	AHE	**99.31**	**23.89**	**2.41**
	CLAHE	0	100	0
	GHE	97.36	22.07	3.94

Fig. 5. Luma3 Gray scale standard: (a) Not enhanced, (b) AHE, (c) CLAHE, (d) GHE.

V. CONCLUSION AND FUTURE WORK

In this article the aim was to study the environment of facial feature detection under unstable lighting condition, we have presented a framework for real time detection of faces. The face detection is based on Viola Jones algorithm, this study focus most on how to improve face detection using luminance components of colour space. Different colour spaces were studied to choose gray scale standard. We have chosen standards which separate luminance to chrominance; these standards include CIELAB/CIELUV, YCbCr, Y'CbCr, HSV, and HSL…. The most important result obtain is the enhancement using gamma based luma technique as a lighting stabilizer before applying AHE. The enhancement method used is a mixture of global enhancement (Gamma transform) and local enhancement (AHE). The global enhancement stabilised the light while the local enhancement let the system to easily discriminate the main features, like eyes, mouth, and nose. The method leads us to a true positive rate of 99.31% with relative high false positive rate (23.89 %).

A new algorithm to calculate global PSNR of an image folder was proposed. For experiments LFW dataset was used, though no rigid general correlation between global PSNR and gray scale standard was found, experiments has proven that enhancing using CLAHE will produce better TPR than enhancing using GHE and AHE, since the over amplification found in GHE and AHE is not found in CLAHE. The global PSNR algorithm result shows that CLAHE produces better quality image than any other image(because it has the highest PSNR), yet experiments has shown that the quality of image has little impact in very low lighting condition using feature based detection method as seen in Fig. 5. Therefore, for an enhancement technique to be used it should be able to discriminate the facial features.

The work done in this article can be extended in many ways. Some possible directions include, assessing the global PSNR and their face detection accuracy using other enhancing method, also our study was applied on Viola Jones haar like features only, this study can still be expanded to other features like the LBP, the HOG, SIFT… to also study the impact of gray scale standard on detection rate. The proposed method produces a significant false positive rate; other research can be done on how to reduce this false positive rate.

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Critical Success Factors Plays a Vital Role in ERP Implementation in Developing Countries: An Exploratory Study in Pakistan

Naeem Ahmed
PhD Scholar, Department of Computer Science
Federal Urdu University of Arts and Technology
Karachi, Pakistan

Dr. A. A. Shaikh
Assistant Professor, Department of Computer Science
Institute of Business Administration (IBA)
Karachi, Pakistan

Dr. Muhammad Sarim
Assistant Professor, Department of Computer Science
Federal Urdu University of Arts and Technology
Karachi, Pakistan

***Abstract*—The capabilities of an Enterprise Resource Planning (ERP) system to integrate all the business functions needed in a single system with a shared database efficiently and effectively has persuaded organizations to adopt them. In enterprise environment, successful ERP implementation has played a vital role for organizational efficiency. In this respect critical success factors (CSFs) have been identified essential for the successful ERP implementation. The purpose of this paper is to identify and analyze CSFs impacting ERP implementation success in Pakistani Small and Medium Sized Enterprises (SMEs). This paper will help Pakistani SME's on how to obtain better results from ERP implementation focusing on CSFs relevant to them.**

Keywords*—Information System (IS); Enterprise Resource Planning (ERP) System; ERP implementation; CSFs; Pakistani Small and Medium Sized Enterprises (SMEs); Statistical Package for Social Sciences (SPSS)

I. Introduction

The organizations in the current IT age need to use information systems effectively which require an understanding of the organization, management, and information technology that form the information systems [1].

Since the mid-90s, Information System (IS) researchers have concentrated their research efforts on the development and testing of models that help investigate aspects of IS in different environments. As a result, a series of models to study the use of ERP Systems, their effect on end-user and other related topics, including system success and their effect on business in the organizations [2].

Enterprise Resources Planning (ERP) is an information system designed for the integration and optimization of processes, as well as transactions in an organization. ERP is universally accepted by organizations throughout the world as a professional solution to achieve desired business goals [3].

ERP projects usually require the investment of a large amount of capital, time, and other business resources. As process orientation is proving to have positive effects on organizational efficiency and performance [4], many organizations are moving from a functional to a process-based IT infrastructure, with ERP systems comprising the central component of such an infrastructure. However, ERP systems provide standardized processes/features to support work procedures or user tasks, which are, in most cases, not perfectly matched. User requirements are also very likely to change after the initial implementation period of the ERP system, for reasons both internal – business process improvement and redesign projects, and external – competitors' moves or changing government regulations. Managing changes in user requirements, and at the same time, maintaining users' satisfaction and benefits, becomes a critical organizational issue for the success of their costly ERP projects post-implementation [5].

For the development of the organization when investing in IT, the project must be calculated according to its capacity, timely delivery, cost, risk avoidance and quality keeping [6].

In the 1980s the word Critical Success Factors (CSF) was introduced under research work, in order to determine why some organizations have been more successful than others. The term Critical Success Factors (CSF) is defined as "those things that must be done if a company is to be successful" and it is quantifiable and controllable [7].

Since then the large organizations targeted by the ERP markets have become saturated, ERP system vendors have now shifted to Small and Medium-sized enterprises (SMEs) market. Resultantly a largely fragmented ERP market has emerged into all the industries of all sizes [8].

II. Research Objectives

This study focuses on determining which factors are critical to implementing ERP successfully in SMEs in Pakistan.

The objectives of this paper are to

- identify the CSFs for ERP Implementation;
- study the impact of CSFs on ERP success in Pakistani SMEs;
- recognizing the impact on organizational and technological aspects; and

- define a framework for successful ERP implementation in Pakistani SMEs.

III. Literature Review

Legacy systems constituted the early enterprise systems within organizations. These systems usually resolved specific departmental needs but did not have the capacity to integrate them. Therefore, it was usual to collect and process the same information several times in different places, creating a serious challenge when policy makers tried to access the right piece of real-time information. This platform generated serious asymmetries between different functional groups within the same organization [9]. To overcome these issues, new systems came into being, known as “Enterprise Resource Planning” (ERP), a term coined by Gartner Group [10].

A. *ERP Implementation*

Implementation of information systems (IS) in general is quite difficult. It is dependent upon organization size, scope and organization process complexity. According To ERP report 2016 From Panorama Consulting Group LLC, [11], results shows that ERP implementation success rate is 57% and only 7% ERP implementation fails to get desired results these results shows that ERP success rate is on the higher side.

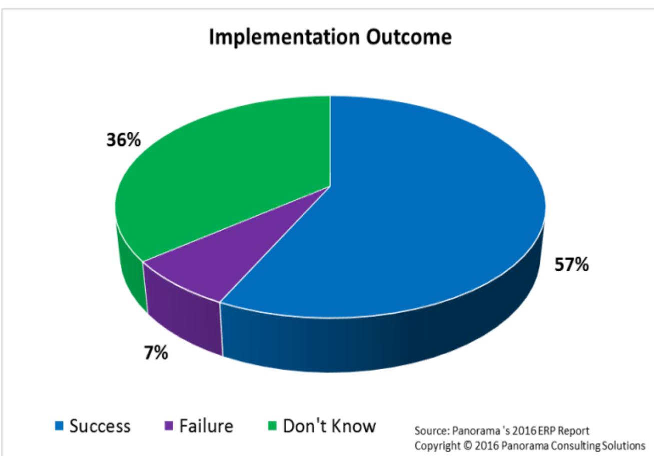

Fig. 1. ERP implementation outcome.

ERP implementation is very important - a survey in 2013 shows that 54% of ERP projects were reported to be cost overruns, 72% were late and 66% of companies the implementation of ERP software initiatives received less than 50% of the expected measurable benefits [12] as shown in Fig. 1.

B. *ERP Implementation in Large Enterprises*

Large Enterprises have streamline processes, proper IT Infrastructure and qualified personnel in their organizations. Large-size organizations have sufficient funds and a proper structured predefined flow of processes. That is why ERP implementation in large enterprises is prone to succeed. Large Enterprises (LE’s) invest huge money in ERP Implementation to get desired results quickly as possible and they achieve their goals within targets (budget, time, accuracy) [13].

C. *ERP Implementation in Small and Medium Size Enterprise (SMEs)*

SMEs are increasingly in focus because of their huge potential for growth and vary in size, age, sector and knowledge base with innovative capacity [14].

They constitute the vast majority of industrial units and services worldwide and are a source of employment. High-tech SMEs embraced, high quality standards and competitiveness and have continued expanding faster than the rest of the industrial economy [14].

The SME sector in Pakistan contributes to nearly 30% of GDP in Pakistan and, contains about 12 million units and employing nearly 30 million peoples. The sector adapted and restructured to face competition from global players to respond quickly [15].

In the industrial development of a country the importance of the SME sector cannot be overemphasized. SMEs constitute nearly 90% of all businesses in Pakistan; employ 80% of the non-agricultural labor; and their share in the annual GDP is about 40% [16]. However, unlike large enterprises in the formal sector, small and medium enterprises are limited by financial and other resources.

IT is recognized as a viable, competitive actor facilitating increased productivity, better profitability, and value for customers [17]. The role of Information Technology (IT) in competitiveness has been mainly focused on large organizations. However, on the world market today, and in the era of e-commerce, small and medium size enterprises (SMEs) can use IT to improve their competitive positions with their larger counterparts [18]. Quigley et al. [19] showed that small businesses are using the Internet more than their counterparts. To take full advantage of IT and compete in the global business environment, business leaders must recognize the strategic value of IT and to exploit it.

Pakistan is a developing country, which is why many organizations have not implemented proper IT infrastructure. In a survey conducted by Irfan et al. [20], only 16% SMEs were using computers.

Although ERP systems were first designed to run in large companies, SMEs were increasingly motivated to introduce ERP [21]. SMEs attempted to improve their organizational performance by implementing ERP in their organizations but did not achieve desired results. Many small businesses still use outdated applications that do not support the emerging business practices [22].

Saini et al. [23] concludes that SMEs have the same needs as large enterprises, but face different challenges because of their limited resources and financial capabilities. Marsh [24] confirmed that SMEs do not have sufficient resources or are not willing to devote a significant part of their resources to a complex ERP implementation process. A better understanding of the ERP implementation in SMEs is necessary to ensure to get high results from ERP.

D. *ERP Implementation Success*

In fact, implementing ERP systems is now a common practice in the world. Although ERP is now a very common phenomena, but the ratio of unsuccessful implementation of ERP is still high [25].

The literature review shows that successful implementation of ERP and failure is not conclusive. While some analysts point positive impacts and results of the ERP application, others report ERP failures. One of the reasons for these different points of views lies in the multidimensionality of the concept of success and difficulty of developing a single success and failure measurement [26].

If these goals are set before ERP implementation begins, the benefits or targets will be evaluated based on whether these goals are achieved or not. If these goals are not set before ERP implementation begins, the ERP will not be able help to get desired results, as targets will change. ERP success and failure depends upon what you want to achieve from ERP and whether it is achievable or not.

E. *Critical Success Factors (CSFs)*

The concept of 'success factors' was first introduced by Daniel (1961) in his seminar HBR article "Crisis of management information". He differentiates between three types of useful data for companies: environmental, competitive and internal; and argues that the enterprise information system (IS) should be discriminatory and selective in reporting internal data. An IS should focus on the factors of success, which according to him usually are three to six for most of the companies in an industry and are defined as those key jobs which must be done exceedingly well for a company to be successful [26].

One of the main research issues in today's ERP systems is to study the ERP implementation success. Critical success factors (CSF) are those factors which are essential to achieve organizational desired goals from ERP.

Many studies have sought to identify factors that positively affect the success of ERP installations. Relevant studies include Li, Hsing-Jung et al. [27], Kulkarni et al. [28], Baykasoğlu et al. [29], Nagpal et al. [30], Saygili et al. [31], Lloyd Miller et al. [32], Kalinga et al. [33], among others.

The success of all ERP projects depends directly on the success of the CSFs. Some other studies related to CSFs on projects have mainly explored the four issues.

- What are the critical factors that influence the success of ERP Implementation at SMEs?
- Which critical factors should get high priority in judging the success of ERP implementation at SMEs?
- What factors are there to illustrate the success of ERP implementation?
- What factors led to successful ERP in a coherent manner?

IV. Research Methodology

The main purpose of this research was to determine the factors that contribute to the success and failure of ERP implementation in Pakistani SMEs. In this research, qualitative analyses with quantitative ratings have been used to create the summary. The research is focused on "Pakistani SMEs and Pakistani ERP Consultants (Specific to Pakistan)".

In this research, ERP Implementation success is considered the dependent variable and organizational factors, human resources factors, project management factors, ERP factors are taken as independent variables. Data is collected through a customized questionnaire and then analyzed.

A questionnaire was developed for this study. The draft of the questionnaire items was extracted from various previous research studies and adapted for this research.

A two-part survey was developed to collect data for analysis and hypothesis testing. The questionnaire was developed in two phases. This method is a popular method to design proper well defined questionnaire used in various research [34], [35].

Phase 1: A pilot questionnaire was sent out. The draft of the questionnaire was developed was from previous research studies and customized for our research. This pilot questionnaire was further examined by 10 ERP Implementation experts, who had experience in the use of enterprise information systems such as SAP, Oracle Businesses Suite, MS Dynamics, or any home-grown ERP system.

Phase 2: The questionnaire was revised accordingly and used it in a pilot test-II with 15 Pakistani ERP consultants. Therefore, the initial survey instrument was revised extensively. Research methodology framework described in Fig. 2.

The survey, respondents were requested to provide answers on a 5-point Likert scale.

- 5 - Strongly Agree
- 4- Agree
- 3 - Neutral
- 2 - Disagree
- 1 - Strongly Disagree.

In the case of respondents from leading organizations, the research questionnaire was intended for those individuals who played a leading role in the ERP implementation (i.e. ERP Manager, ERP Project Managers, Head of IT, etc.). They had insight into their projects and were able to answer the survey questions and evaluate the measures included in the questionnaires.

During the research 400 respondents were contacted and 60 responses were obtained (response rate is 15%) from companies representing various industries in Pakistan.

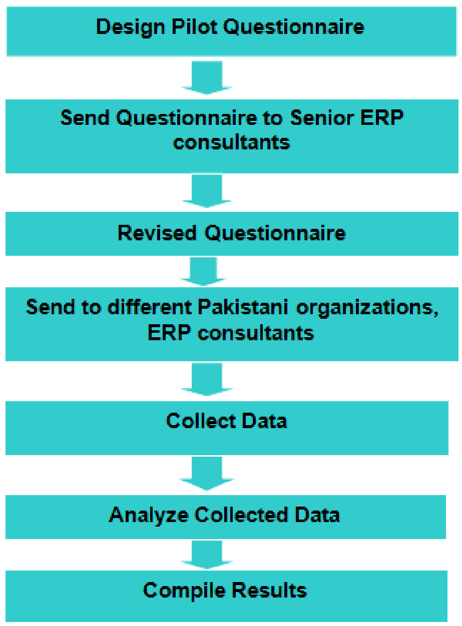

Fig. 2. Research methodology framework.

V. Results And Discussion

In order to illustrate the respondents' point of view on regarding the importance of proposed factors, an average was calculated for each factor. These calculations have been made from all experts opinions.

CSFs for successful ERP implementation in Pakistani SMEs have been identified through extensive literature review and further examining by ERP Implementation experts, then determining whether it was complete and clear. Most of the earlier research has not specifically focused on SME sector and the research has been broad based. It has been assumed that CSFs identified from ERP implementation and other industries will be applicable for ERP implementation in SMEs. In this study, a total of 38 CSFs have been identified which are grouped in 4 Categories (describe in Fig. 3). The same is presented in Appendix I.

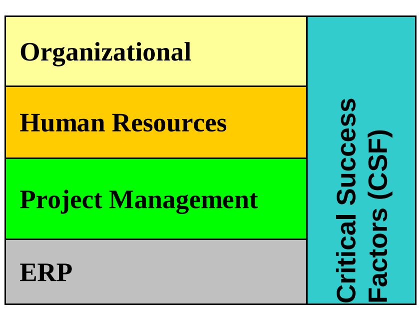

Fig. 3. High level research conceptual model.

SPSS (Statistical Package for Social Sciences) was used as data analysis software Package. SPSS further refined the results and output data in different ways (i.e. validity test, reliability test, factor analysis etc.).

A. Reliability Test

Reliability test for the instruments were conducted from the survey data. The Cronbach coefficient (α) was calculated to test the reliability and internal consistency of the responses. Cronbach's alpha reliability coefficient normally ranges between 0 and 1. The closer the coefficient is to 1, the greater is the internal consistency of the items (variables) in the scale.

The value of α in this study was found to be **0.949** (Cronbach's alpha reliability coefficient normally ranges between 0 and 1) which is considered highly acceptable. After conducting reliability test, the data was analyzed to obtain the final results.

B. Validity Test

Validity is a measure of the degree of validity or validity of a research instrument. An instrument is said to be valid if it can measure what is to be measured or desired. An instrument is said to be valid if data for the studied variables can be revealed.

For the group of 60 respondents from Pakistani SMEs validity was found to be **0.9747**.The validity was found by using Guilford's formula i.e. by applying the square root of the reliability.

C. Demographic Analysis

Demographic analysis is shown in Fig. 4 and respondent industry type results are present in Table 1 and Fig. 5.

Respondents' qualification analysis is shown in Fig. 6.

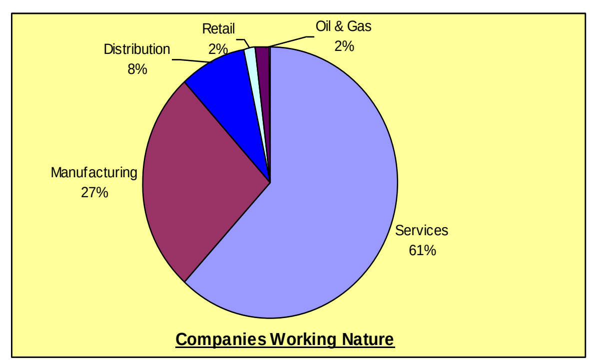

Fig. 4. Companies working nature.

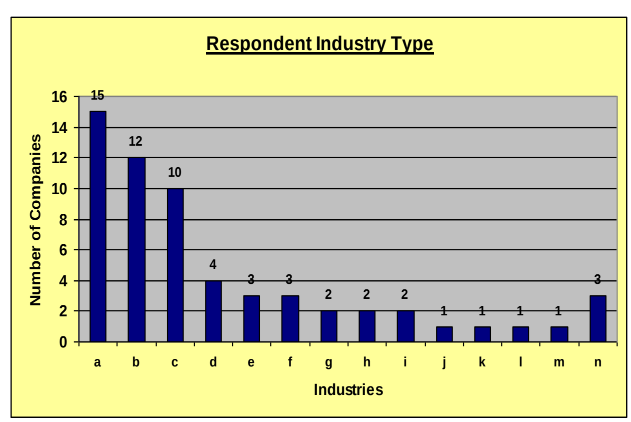

Fig. 5. Respondent industry type.

TABLE I. RESPONDENT INDUSTRY TYPE

Id	Industries	Number of Companies
a	Computer Service	**15**
b	Pharmaceutical	**12**
c	Healthcare	**10**
d	Aviation	**4**
e	Telecommunication	**3**
f	ERP Consultant Firm	**3**
g	Bank	**2**
h	NGO	**2**
i	Utilities	**2**
j	Electronic and Electrical	**1**
k	Energy Services	**1**
l	Insurance, Life and Health	**1**
m	Oil & Gas	**1**
n	Others	**3**

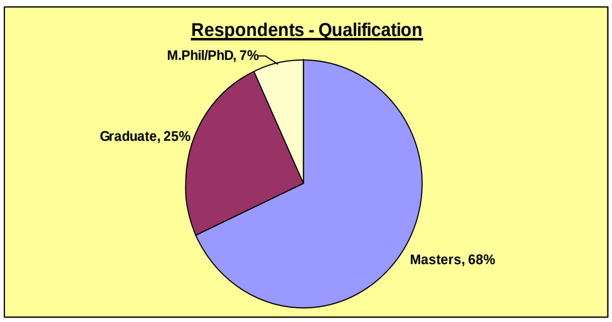

Fig. 6. Respondents – qualification.

D. Descritptive Analysis

Table 2 presents basic statistics including mean, standard deviation, mode and variance. The values were well understood in the desirable levels and the analysis of the principle components had to be used to extract the main factors. The values were well within desirable levels and analysis needs to extract the main factors.

Where,

N: This is the number of valid observations for the variable.

Mean: This is the arithmetic mean across the observations. It is the most widely used measure of central tendency. It is commonly called the average. The mean is sensitive to extremely large or small values.

Variance: The variance is a measure of variability. It is the sum of the squared distances of data value from the mean divided by the variance divisor. The Corrected SS is the sum of squared distances of data value from the mean. Therefore, the variance is the corrected SS divided by N-1.

Standard Deviation: Standard deviation is the square root of the variance. It measures the spread of a set of observations. The larger the standard deviation is, the more spread out the observations are.

Skewness and Kurtosis are used to validate the data for normality [36]. Table 3 presents including min, max, Skewness and Kurtosis.

Skewness: Skewness measures the degree and direction of asymmetry. A symmetric distribution such as a normal distribution has a Skewness of 0. A positive Skewness value indicates positive (right) skew; a negative value indicates negative (left) skew. The higher the absolute value, the greater the skew is.

Kurtosis: Kurtosis is a measure of tail extremity reflecting either the presence of outliers in a distribution or a distribution's propensity for producing outliers, a positive kurtosis value indicates positive kurtosis; a negative one indicates negative kurtosis. The higher the absolute value, the greater the kurtosis is (shown in Table 3).

TABLE II. DESCRIPTIVE STATISTICS

CSF #	N	Mean	Std. Error of Mean	Med	Mod	Std. Dev	Var
C1	60	4.8	0.1	5	5	0.459	0.210
C2	60	4.5	0.1	5	5	0.671	0.451
C3	60	4.3	0.1	4	5	0.767	0.588
C4	60	4.3	0.1	4	5	0.793	0.629
C5	60	4.2	0.1	4	4	0.713	0.509
C6	60	4.4	0.1	4.5	5	0.726	0.528
C7	60	4.3	0.1	4	5	0.715	0.511
C8	60	4.3	0.1	4	5	0.719	0.517
C9	60	4.2	0.1	4	4	0.694	0.481
C10	60	4.6	0.1	5	5	0.579	0.336
C11	60	4.6	0.1	5	5	0.560	0.313
C12	60	4.5	0.1	5	5	0.646	0.418
C13	60	4.5	0.1	5	5	0.695	0.484
C14	60	4.5	0.1	5	5	0.695	0.483
C15	60	4.3	0.1	4	4	0.637	0.406
C16	60	4.5	0.1	5	5	0.619	0.383
C17	60	4.5	0.1	5	5	0.593	0.351
C18	60	4.4	0.1	4.5	5	0.617	0.381
C19	60	4.4	0.1	4	5	0.615	0.379
C20	60	4.5	0.1	5	5	0.671	0.450
C21	60	4.4	0.1	5	5	0.714	0.510
C22	60	4.2	0.1	4	5	0.777	0.604
C23	60	4.3	0.1	4	4	0.647	0.419
C24	60	4.3	0.1	4	4	0.672	0.452
C25	60	4.2	0.1	4	4	0.743	0.552
C26	60	4.4	0.1	5	5	0.754	0.569
C27	60	4.5	0.1	5	5	0.717	0.514
C28	60	4.4	0.1	5	5	0.714	0.510
C29	60	4.4	0.1	5	5	0.799	0.638
C30	60	4.5	0.1	5	5	0.647	0.418
C31	60	4.4	0.1	5	5	0.732	0.536
C32	60	4.3	0.1	4	5	0.750	0.563
C33	60	4.2	0.1	4	4	0.721	0.519
C34	60	4.2	0.1	4	4	0.658	0.433
C35	60	4.2	0.1	4	5	0.792	0.627
C36	60	4.1	0.1	4	5	0.827	0.684
C37	60	4.5	0.1	5	5	0.671	0.451
C38	60	4.5	0.1	5	5	0.695	0.483

TABLE III. SKEWNESS AND KURTOSIS

CSF #	N	Min	Max	Skewness	Std. Error of Skewness	Kurtosis	Std. Error of Kurtosis
C1	60	3	5	-1.858	0.304	2.705	0.599
C2	60	3	5	-1.007	0.304	-0.138	0.599
C3	60	3	5	-0.482	0.304	-1.132	0.599
C4	60	3	5	-0.538	0.304	-1.198	0.599
C5	60	3	5	-0.274	0.304	-0.972	0.599
C6	60	3	5	-0.665	0.304	-0.813	0.599
C7	60	3	5	-0.531	0.304	-0.874	0.599
C8	60	3	5	-0.574	0.304	-0.861	0.599
C9	60	3	5	-0.365	0.304	-0.857	0.599
C10	60	3	5	-1.312	0.304	0.796	0.599
C11	60	3	5	-0.909	0.304	-0.171	0.599
C12	60	3	5	-0.879	0.304	-0.259	0.599
C13	60	3	5	-1.058	0.304	-0.147	0.599
C14	60	3	5	-0.942	0.304	-0.335	0.599
C15	60	3	5	-0.333	0.304	-0.637	0.599
C16	60	3	5	-0.669	0.304	-0.471	0.599
C17	60	3	5	-0.604	0.304	-0.548	0.599
C18	60	3	5	-0.611	0.304	-0.524	0.599
C19	60	3	5	-0.555	0.304	-0.566	0.599
C20	60	3	5	-0.89	0.304	-0.322	0.599
C21	60	3	5	-0.823	0.304	-0.581	0.599
C22	60	3	5	-0.421	0.304	-1.214	0.599
C23	60	3	5	-0.425	0.304	-0.662	0.599
C24	60	3	5	-0.488	0.304	-0.723	0.599
C25	60	3	5	-0.242	0.304	-1.131	0.599
C26	60	3	5	-0.786	0.304	-0.795	0.599
C27	60	3	5	-0.928	0.304	-0.447	0.599
C28	60	3	5	-0.823	0.304	-0.581	0.599
C29	60	3	5	-0.869	0.304	-0.862	0.599
C30	60	3	5	-0.94	0.304	-0.165	0.599
C31	60	3	5	-0.758	0.304	-0.736	0.599
C32	60	3	5	-0.502	0.304	-1.047	0.599
C33	60	3	5	-0.31	0.304	-1.001	0.599
C34	60	3	5	-0.18	0.304	-0.660	0.599
C35	60	3	5	-0.397	0.304	-1.290	0.599
C36	60	3	5	-0.123	0.304	-1.530	0.599
C37	60	3	5	-1.007	0.304	-0.138	0.599
C38	60	3	5	-1.118	0.304	-0.036	0.599

Above results shows that which CSFs are the most critical in ERP Implementation process.

E. Top Critical Success Factors

Respondents considered that the top management support and commitment was the most important according to the analysis in Organizational category. Organization clearly defined strategic goals is second highest CSF in organizational category. An effective management technique is third highest CSF in organizational category (shown in Fig. 7).

Respondents considered that the Human motivation, support and consideration were the most important according to the analysis in HR category. Qualified skilled staff is second highest CSF in HR category. Proper rewards system is third highest CSF in HR category (shown in Fig. 8).

Respondents considered that the Realistic expectation of top management and enterprise were the most important according to the analysis in project management category. Clear Project objective, mission, strategies and direction is second highest CSF in project management category. Well-designed project schedule and plan is third highest CSF in project management category (shown in Fig. 9).

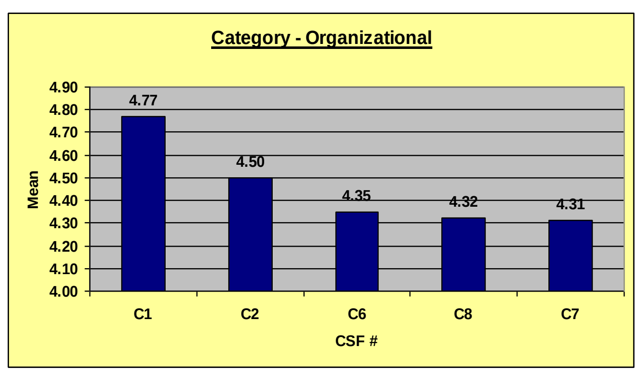

Fig. 7. Top CSFs - category – organizational.

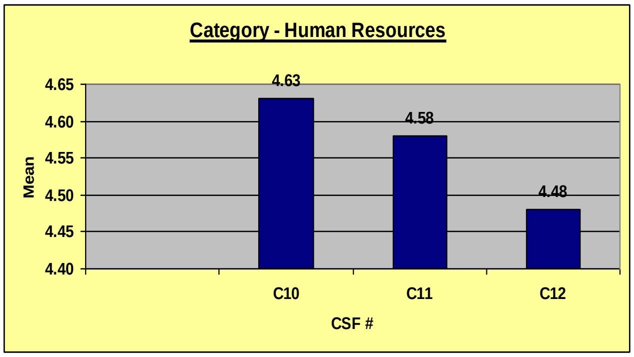

Fig. 8. Top CSFs - category - human resources.

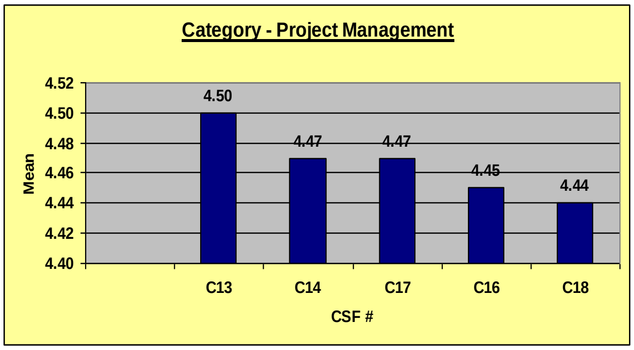

Fig. 9. Top CSFs - category - project management.

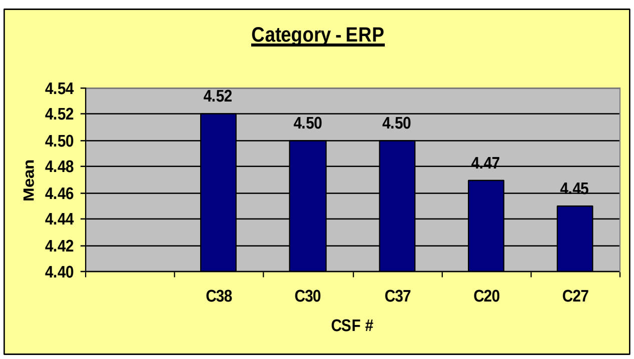

Fig. 10. Top CSFs - category – ERP.

Respondents considered that the End User Training were the most important according to the analysis in ERP category. Reliability of ERP is second highest CSF in ERP category. Proper ERP user documentation is third highest CSF in ERP category (shown in Fig. 10).

VI. Conclusion

This study examines ERP implementation projects using a proposed success factor model. The model was defined based on a thorough review of the literature and feedback from ERP Experts, and the factors were grouped using the own novel categorization for this study. In addition, this research uses its own proposal of synthetic measurement of successful implementation.

The main contribution of this article is one of the first comprehensive studies in the influence of particular factors on the success of ERP projects in Pakistan. This research goes beyond simply stating the subjective opinions of respondents and illustrating the real impact of factors on the success of the ERP project, recognizing those who have the most influence.

This study bridges the gap in the existing literature with an emphasis on the SME sector, as previous research in this area was not focused on the SME sector.

38 CSF were identified from the existing literature and then grouped into four using factor analysis (Appendix 1). The results of the research clearly indicated that leadership qualities played an important role in obtaining top management support for successful ERP implementation.

ERP consultants and ERP vendors will benefits from the guidelines for successful ERP implementation for Pakistani SMEs. The key results were described in management and non-management factors.

A. *Management Factors*

- Top management commitment and organizational support are necessary for successful ERP implementation in Pakistani SMEs.
- End User motivation, support and consideration are also play a vital role for successful ERP implementation in Pakistani SMEs.
- Qualified Staff is another factor for successful ERP implementation in Pakistani SMEs.
- A clear business plan, vision, goals and objectives are essential to guide an ongoing organizational effort to successfully implement ERP.
- The success of ERP implementations depends on user involvement that makes the user comfortable with ERP systems and increases their expertise and knowledge.
- A key factor for the successful implementation of ERP requires a corporate culture that emphasizes the value of sharing common goals in relation to individual activities and the value of trust between partners, employees, Managers and businesses.

B. *Non-Management Factors*

- Training and education of End user are an important factor for successful ERP.
- ERP Proper documentation is essential for ERP implementation.
- Good IT infrastructure is required for ERP execution.
- ERP System has a well-defined consistent interface which leads to end user satisfaction.

VII. Practical Implications

The results of this study have important practical and research implications. The main conclusions of this study would be of great value for the management of Pakistani SMEs in making decisions about ERP adoption. In addition, it provides information systems researchers and ERP consultants with a better understanding of the adoption of ERP systems in the context of developing countries like Pakistan to ensure the successful implementation of the ERP. However, it should be recognized that, since this research emerges from a single, in-depth case study, the ability to generalize the findings is limited. The results of the study are expected to be more transferable in the context of Pakistani SMEs in general. In addition, it also provides a benchmark to further enhance the scope of ERP implementation research in Pakistani SMEs among academics and researchers.

VIII. Research Limitation

This study fills the gaps in literature by proposing a model of critical success factors in ERP implementation focusing Pakistani SMEs.

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APPENDIX 1

List of Critical Success Factors (CSFs):

CSF #	Organizational
C1	Top management support and commitment
C2	Organization clearly defined strategic goals
C3	Progressive corporate culture and work climate
C4	Aligned business process
C5	Innovation and competitiveness
C6	Effective management techniques
C7	Good change management and organizational adaptability
C8	Good crisis management and ability to handle surprises
C9	Adequate control system, monitoring and feedback

CSF #	Human Resources
C10	Human motivation, support and consideration
C11	Qualified skilled staff
C12	Proper rewards system to encourage ideas and innovation

CSF #	Project Management
C13	Realistic expectation of top management and enterprise
C14	Clear Project objective, mission, strategies and direction
C15	ERP Project tasks are reviewed on a periodic basis
C16	Good project communication
C17	Well-designed project schedule and plan
C18	Well defined controlled budget for ERP implementation
C19	Good IT infrastructure

CSF #	ERP
C20	Clear goals & objectives (get from ERP)
C21	Controlled ROI on ERP implementation
C22	ERP Benchmarking to identify cutting-edge ERP techniques
C23	Best Consultant selection
C24	Best ERP package selection
C25	External Consultants involvement in the ERP system implementation
C26	Vendor support
C27	Top Management satisfaction with ERP System
C28	End User satisfaction with ERP System
C29	Relationship of trust among all parties concerned
C30	Reliability of ERP
C31	Well-designed ERP System interface
C32	Aligned between organization culture and ERP system
C33	Aligned between organization structure and ERP system
C34	Good business process reengineering (BPR)
C35	Legacy systems management

A Survey on Smartphones Security: Software Vulnerabilities, Malware, and Attacks

Milad Taleby Ahvanooey*, Prof. Qianmu Li*, Mahdi Rabbani, Ahmed Raza Rajput
School of Computer Science and Engineering, Nanjing University of Science and Technology,
Nanjing, P.O. Box 210094 P.R. China.

***Abstract*—Nowadays, the usage of smartphones and their applications have become rapidly popular in people's daily life. Over the last decade, availability of mobile money services such as mobile-payment systems and app markets have significantly increased due to the different forms of apps and connectivity provided by mobile devices, such as 3G, 4G, GPRS, and Wi-Fi, etc. In the same trend, the number of vulnerabilities targeting these services and communication networks has raised as well. Therefore, smartphones have become ideal target devices for malicious programmers. With increasing the number of vulnerabilities and attacks, there has been a corresponding ascent of the security countermeasures presented by the researchers. Due to these reasons, security of the payment systems is one of the most important issues in mobile payment systems. In this survey, we aim to provide a comprehensive and structured overview of the research on security solutions for smartphone devices. This survey reviews the state of the art on security solutions, threats, and vulnerabilities during the period of 2011-2017, by focusing on software attacks, such those to smartphone applications. We outline some countermeasures aimed at protecting smartphones against these groups of attacks, based on the detection rules, data collections and operating systems, especially focusing on open source applications. With this categorization, we want to provide an easy understanding for users and researchers to improve their knowledge about the security and privacy of smartphones.**

Keywords—Mobile security; malware; adware; malicious attacks

I. Introduction

These days, smartphones are widely used and provided an abundance of capabilities like personal computers (PCs) and, moreover, offer lots of connection options, such as 3G, 4G, Wi-Fi, GPS, LTE, NFC, and Bluetooth. This plethora of appealing properties has led to a widespread distribution of smartphones which, as a result, are now ideal targets) for malicious writers. Basically, mobile operating systems (OS) can be vulnerable and suffered from malicious attacks due to running a lot of applications (apps) during the web surfing or downloading apps from the Internet. Nowadays, people have more awareness about various smartphones and their companies, but a very few of them have enough information about mobile OSes and its vulnerabilities [1], [2]. As a result, Android OSes are more popular than the desktop OSes (i.e., Windows, Mac, UNIX and Linux, etc.) and in general smartphone usage (even without tablets) is outnumbered than desktop usage (desktop usage, web usage, overall is down to 44.9% in the first quarter of 2017). Further, based on the latest report released by Kaspersky on December 2016 [3], 36% of online banking attacks have targeted Android devices and increased 8% compared to the year 2015. In all online banking attacks in 2016, have been stolen more than $100 million around the world. Although Android OS becomes very popular today, it is exposing more and more vulnerable encounter attacks due to having open-source software, thus everybody can develop apps freely. A malware writer (or developer) can take advantage of these features to develop malicious apps. Because of the malware apps, smartphones can be easily vulnerable to malicious activities such as phishing, hijacking, hacking, etc. which might steal the sensitive information without the user's knowledge [4]. Since the mobile OSes can be installed on other devices, like tablets, phablets, etc., the same security issues are existed. For example, most of the users used to download and install third-party apps (e.g., games, photography apps, etc.). Due to this reason possibility of installing malware and adware apps is increasing as well. In general, users utilize smartphones for payment transactions increasingly, such as mobile banking and online shopping, and in addition, there are probably more fake apps (i.e. malware apps in cover of real apps) that designed to make profits for malicious writers [5]-[7].

The main contributions of this survey are summarized as follows.

- We review different mobile OSes and their features (e.g. architecture, security mechanisms, etc.)
- We investigate about sensitive security issues affecting on smartphones such as malware attacks, vulnerabilities and categorize them over the period of 2011 to 2017 by focusing on software attacks.
- We present some trusted security countermeasures to help the users in order to protect their devices.
- We suggest some research points for future works.

The rest of this paper is organized as follows. Section 2 presents a review of existing literature about smartphone OSes. Section 3 describes different types of malware, software attacks or threats, vulnerabilities and discusses current threats targeting smartphones OSes. Section 4 introduces some most wanted mobile malware families in 2016 and 2017. Section 5

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presents some existing security countermeasures against threats for smartphone users. Section 6 suggests some research areas about malware detection techniques for cyber security researchers. Finally, Section 7 draws some conclusions.

II. Smartphone Operating Systems

A. Definition

A smartphone OS (or Mobile OS), is a system software which is able to run on smart gadgets (e.g., smartphones, tablets, phablets and other support devices), that allows it to run other applications developed for its platform. In other words, the smartphone OS is responsible for determining the features and functions available on the device, such as keyboards, thumbwheel, WAP, and synchronization with apps, etc. Basically, it provides a layer on the device to run apps, scheduling tasks and controlling peripherals (e.g. network connections, output peripheral devices, etc.). As the general architecture of a smartphone OS depicted in Fig. 1, it placed between hardware and applications in order to manage the relations with them [8].

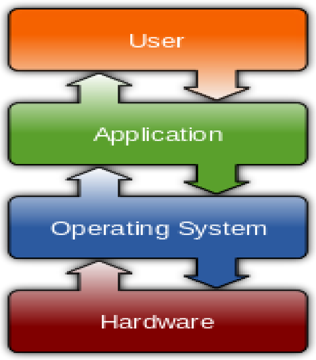

Fig. 1. Smartphone OS architecture.

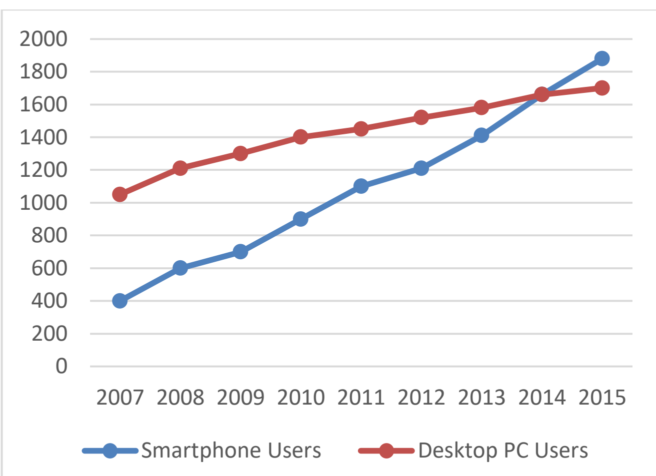

Fig. 2. Number of internet users (millions) [10].

Currently, most of the Internet users are connected via a smartphones, tablets and PCs. According to the latest report by ComScore [9], which is depicted in Fig. 2, there were two different groups of the Internet users: the first group "desktop PC users" and second ones "smartphone users" and, in addition, there were more than 1.8 billion smartphone users until the end of March 2015. It means that the number of smartphone Internet users are outnumbered than desktop users due to the popularity of smartphones in recent years [10].

B. Smartphone OS Features

Technically, smartphones have different features from one to another, which are dependent on the technologies owned (e.g. Camera, fingerprint, Sensors, and NFC, etc.). Due to having different technologies, the OSes should provide proper control of them. On the other hand, unlike hardware features, the OSes also have various features that determine how to exploit smartphones by using apps such as running apps, multitasking, security, etc. Therefore, popular smartphone OSes can be classified in five different categories such as Android, Apple iOS, Microsoft Windows Phone, BlackBerry, and others. These days, there are so many third-party apps that are available for smartphones on the online markets (or app stores) and are increasing rapidly. On the other hand, there are some default apps that initially installed on the OS such as Web browser, email, text messenger, navigator and app stores etc. The most malware apps are hidden under the cover of normal apps and shared on the online markets, but users cannot guess about whether they are malware or real apps [4], [11].

App Store (Market): App store is an online market which providing to browsing and purchasing many apps for smartphone users such as Google Play Store (Android), Apple Store (iOS) and Microsoft Store (Windows Phone), etc. In fact, anyone can develop an app and share it on the app stores to earn money or personal gain [12]. Commonly, all app stores check the apps by high-level anti-malware before releasing them. Moreover, current anti-malware companies utilized-malware detection techniques such as signature based and machine learning (behavior) techniques, but still these techniques are not efficient to identify new unknown malware [13], [14], [73].

In continue, we present an overview of most popular smartphone OSes and describe their system architectures.

- **Android** is an open-source OS developed by the Google, based on the Linux kernel and designed primarily for touchscreen devices. As shown in Fig. 3, Android OS is consisted four main layers namely: Linux kernel, Libraries, Java API Framework, and System Apps [15]-[17].

- **The Linux kernel** is responsible for managing core system services such as virtual memory, physical device drivers, network management, and power management.

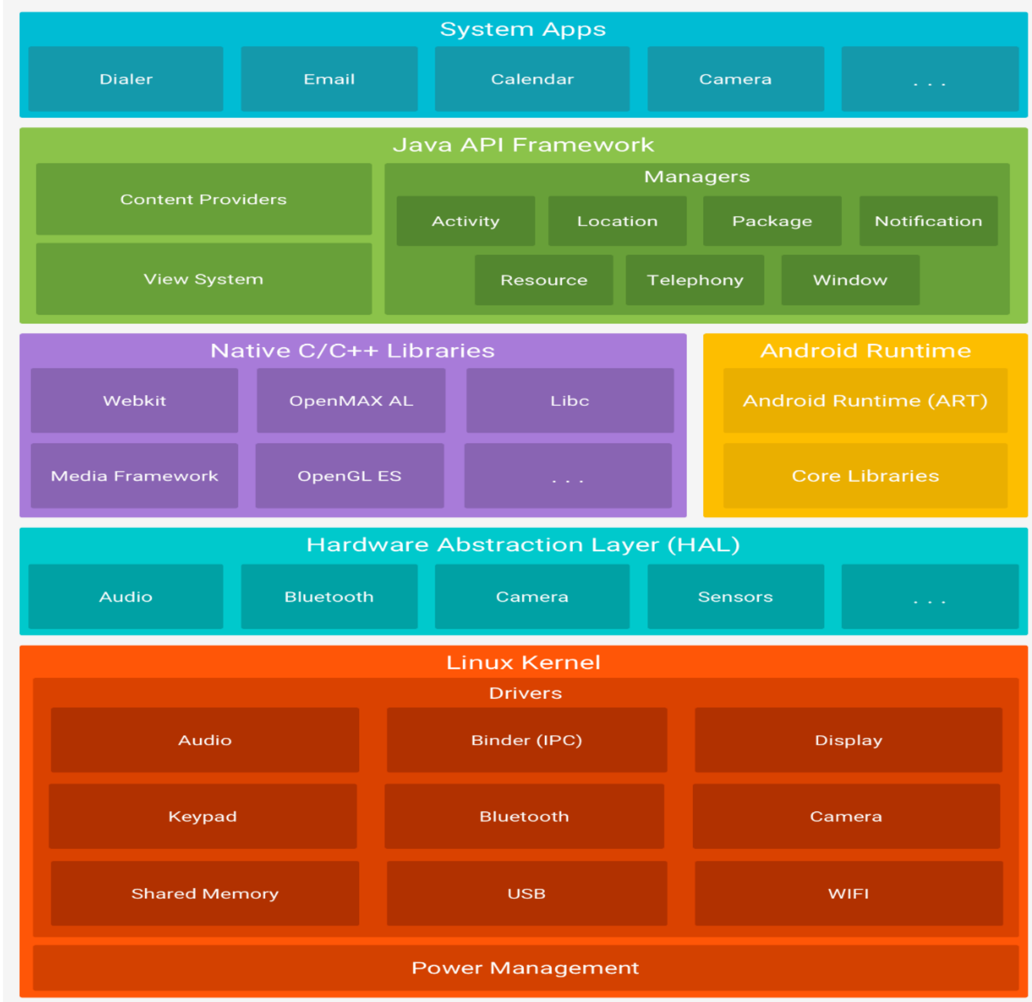

Fig. 3. An illustration of android architecture [18].

- **Libraries:** This layer is hosted upon the Linux kernel and consisted OpenGL|ES, audio manager, open-source Web browser engine WebKit, SQLite database which is useful storage for saving and sharing data and, in addition, SSL libraries are responsible for the Internet security, etc.

a) Android Libraries: This group is contained those Java-based libraries which are designed especially for developing apps. In addition, these libraries included some facilities for developers such as user interface building, graphics drawing and database access (e.g. “Android.app”, “Android.database”, “Android.opengl”, and “Android.view”, etc.). Basically, the Android OS is written in C/C++ and has covered the Java-based core libraries in the Android runtime. In general, most of the Android apps written in Java, however, there are some other platforms for developing apps by C/C++, Python, and Basic, etc. [11].

b) Android Runtime: This part contained a component which is called ‘Dalvik’ Virtual Machine (or Android Run Time (ART) is the next version of Dalvik) which is a type of Java Virtual Machine especially developed and optimized for the Android OS. The Dalvik VM utilizes the Linux core features like multi-threading and memory managements, which is essential for the Java language. The Dalvik VM enables every Android app to execute in its own process with its own space of the Dalvik. Moreover, the Android runtime also provided a set of core libraries for developers to write Android apps using standard Java language.

- **Java API Framework:** This layer provided many services for apps using the Java classes. The developers are allowed to make use of these services in their apps. Also, the Application framework consisted key services such as activity manager, content providers, resource manager, notification manager, and view system, etc. [19].

- **System Apps:** Basically, Android has a set of core apps for contacts, SMS messaging, email, calendars, Internet browsing, etc. The apps consisted with the platform have no special status among the apps the user selects to install. Furthermore, a third-party app can be set as a default app (e.g., SMS messenger, web browser, or even the default keyboard, etc.). The system apps operate both as apps for end users and to provide key capabilities which developers can have access from their own app [18].

➢ ***Security:*** The Android was designed with openness in mind, and is favorable to the use of third-party apps and cloud based services. The Google has introduced several security layers for Android OS platforms [20]-[22]. Currently, Android has five key security features including following points.

a) Security at the OS level (Linux kernel): The Linux kernel enabled Android with a set of security measures. It presents a user-based permission model, a secure mechanism for IPC (inter process communication), process isolation and ability to clear any unnecessary insecure parts of the kernel. It also can ban multiple system users from accessing each other's resources and exhausting their effects.

b) Mandatory application sandbox: This feature used a user-based protection to create an "Application Sandbox" such that assigns a unique user ID to each app, and each one run its own process.

c) Secure inter-process communication: Android performs each app at the process level through the Linux kernel, which does not permit apps to interact with the other apps and assigns them only some limited accesses to the Android OS.

d) Application signing: This key feature provided the user permission-based access control and provides a list of permissions on the first page of installation package (APK) that the intended app will utilize (or access) them after running on the device.

e) Application-defined and user-granted permissions: This feature gives a set of file system permissions so that each app has its own files and except a developer explicitly exhibits files to another Android app, files generated by one app cannot be read or changed by another one (i.e., if an organization wants to share data between a few of its own Android apps, it can use 'Content Providers' via custom permissions to share the data). Permission prevents any other apps on the device from accessing the app's data unless access was specifically requested & granted to the intended apps. Once a custom permission is set, only apps which were granted the custom permission can initiate IPC with the protected app). More information can be found in [11], [25].

Recently, the Google provided a way of access control by users in Android 6.x so that the users can enable or disable permissions for apps. Practically, this access provides an option to control the exhausting adware apps as well. It is an efficient option to block the unauthorized permissions for the malicious apps but most of the users do not have sufficient knowledge about the permission accesses.

However, due to the increasing the number of malware attacks targeting Android devices, the existing security mechanisms are not adequate to mitigate malicious attacks. In addition, the popularity of Android OS made it a proper target for the malware developers. In fact, a huge number of malicious attacks are targeting these devices on a daily basis. For example, according to the latest malware evaluation report released by Kaspersky Lab on February 2017 [42], they registered nearly 40 million malicious attacks by mobile malware apps over the Android OS during 2016. Over the reporting period, the number of new malware files increased significantly from 29% in 2015 to 43% in 2016.

- **Apple iOS** (formerly iPhone OS) is a smartphone OS which is designed and developed by Apple Inc. exclusively for its products (e.g. iPhone, iPad, iPod). The iOS has a multilayer architecture and operates as an intermediary between the underlying hardware and the apps running on their devices. The iOS architecture can be classified as a set of four layers, which are depicted in Fig. 4. Lower-layers included fundamental services that all apps rely on it, and moreover, higher-level layers give sophisticated graphic services and interface related services [22].

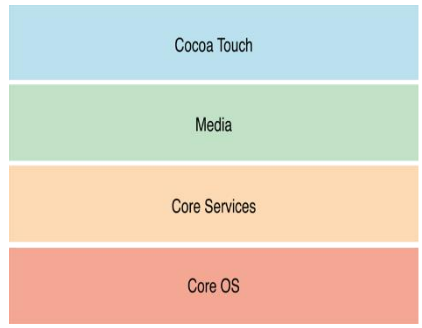

Fig. 4. iOS Architecture [22].

- *Core OS* contained the low-level features such as accelerate frame work, external accessory framework, and Bluetooth framework, etc. (e.g. accelerate frame work included interfaces for executing DSP, Linear algebra and image processing calculations).

- *Core Services* consisted of the high-level features which all apps can use them such as Cloud Kit framework, address book framework, and Core location framework, etc. (e.g. Cloud Kit provided a medium for transferring data between the user's app and iCloud) and in addition, it also included specific interfaces for low-level data types, network connection, startup services and accesses. These interfaces are usually C-based and core-centered that offers several technologies such as SQLite, POSIX threads, and UNIX sockets.

- *Media layer* included game kit, map kit, IAD, UIKit, events (touch), and view controllers. In other words, it provides a data section for using audio, animation, video, text, and image formats (e.g. PNG, JPEG and TIFF).

- *Cocoa Touch* consisted of some key frameworks for developing iOS apps. These frameworks provide basic infrastructures and support for key technologies such as touch-based inputs, multitasking, push notifications, and many high-level system services (i.e. when the developers want to design an app should investigate about the technologies in this layer) [23]-[25].

➢ **Security:** The iOS has provided various APIs to perform security features for developers. The iOS applies a common data security architecture (CDSA) to perform the security features like desktop counterpart and file access permissions on low-level properties which execute by the BSD kernel (UNIX OS based kernel). Moreover, higher level functionality is given by CDSA (e.g. encryption, security data storage, and authentication). The iOS users do not have any control on permissions access to which the app requires to access for doing its job. In fact, the iOS presents a set of limited permissions for third party apps which are required by the app's sandbox, where each app can run separately from other apps on the iOS. Moreover, iOS can block the access of the device's subsystems [26]. Basically, the iOS isolation policy is responsible for handling the permissions which the app requires without asking the user. In some cases, iOS also asks some permission to access the specified resources that have to be accepted by the user of the device. These permissions are included receiving notifications from the Internet, accessing location data (GPS), sending an outgoing SMS or email message and starting an outgoing phone call. Although the Apple iOS has security mechanisms for protecting against malware apps, but still they are increasing via new techniques in the cover of real apps [27]-[29].

- **Windows Phone** (WP) is a smartphone OS which developed by Microsoft for large screen smartphones. For the first time, Windows phone 7 was released in 2010 and received the latest update WP 8.1 and Windows 10 up till now. It also supports large screen tablets, phablets, and X-Box gaming, and provides multitasking, installing third-party apps and games [8], [28]. Microsoft Lumia was the first brand of this family of Microsoft smartphones that received a windows 10 mobile beta update in February 2015. The Windows 10 mobile only can be used for smartphones and phablets which are running on the ARM processor architectures. Microsoft has presented tools for developers to easily port some iOS apps with minimum alterations. The developers can utilize Microsoft Visual Studio for designing WP apps (e.g. Visual Basic .NET and C#), [30]-[32].

➢ **Security:** Currently, Windows 10 mobile utilizes the same security mechanisms like the Windows 10 OS (PC) for protecting against emerging security threats. These mechanisms are consisted windows hello, windows information protection and malware resistance.

a) Windows Hello for Business: This technology provides an identity and access control features that only authorized users could access data and resources. It also presents a secure multi-factor authentication (MFA) deployment and employs a companion device, offering the PIN and biometric authentication methods.

b) Windows Information Protection: This technology enables an automatic data separation for preserving corporate information when they are being shared with personal data and apps.

c) Malware Resistance: This merit technology applies multi-layered protections such as start-up processes, hardware devices and apps platform for reducing the threats of malware.

These days, Windows phone has become less popular than Android and iOS between users, as 0.5% of market share belonged to this OS in 2016. It means that the most malware apps are targeting Android and iOS devices [33]-[35].

- **BlackBerry (RIM)** is developed by BlackBerry for its smartphones and the RIM's Playbook tablet. RIM OS was discontinued after the release BlackBerry 10 in 2012, but this company announced that will continue the support of the RIM OS. BlackBerry 10.x became the fourth most widely used smartphone OSes that has less than 0.2% of the mobile OS market share in 2016. BlackBerry 10 is a Unix-like OS which is called QNX based. It was originally developed by QNX software systems until the company was bought by BlackBerry in April 2010. In addition, the BlackBerry 10 used the application framework Qt (version 4.8) and the features of Android runtime for executing Android apps. On October 2015, the BlackBerry company announced that they do not have plans to release new APIs and software development kits (SDKs) or adopt Qt framework and in next updates (like Qt 5 and BlackBerry 10.3.3, 10.3.4) would only focused on the privacy and security optimizations [31], [36], [37].

➢ **Security:** BlackBerry 10.x provided some key security features such as platform security, secure device management, data in transmission security, and app security, etc.

a) Platform security: This technology verifies the authenticity of the BlackBerry 10.x and its applications when any BlackBerry 10 devices in the world boots up. Basically, This OS is based on QNX Neutrino RTOS that provides a kind of resilience and security protection against tampering, malware and data leakage.

b) Secure device management: This service provides the highest levels of security control for users that can use a specific space for their personal data usage without sacrificing their security needs. It also permits easy access to all the personal accounts and maximizes productivity while seamlessly securing the data.

c) Data in transit security: BlackBerry 10 supports a full range of encryption and authentication approaches, allowing the users to safely connect their devices to networks using the BlackBerry infrastructure, VPN, and Wi-Fi.

d) App security: This technology assigns to all apps in their own sandboxes for securing against data leakage and malware.

However, Blackberry 10.x has owned some security features but since it can be able to run the Android apps, there has been a lot of Android malware that target the BlackBerry 10.x as well [38].

- **Symbian** is a discontinued mobile OS which was originally developed as a closed-source for PDAs in 1998 by Symbian Ltd. This OS was used primarily by Nokia, Sony Ericsson and Motorola with its UIQ user interface up till the end of 2010. In that time, the Symbian Foundation disintegrated and Nokia took back control of the OS development. In February 2011, Nokia was the only remaining company still supporting Symbian outside the Japan, in addition, announced that would prefer to use Microsoft Windows Phone 7 as its primary smartphone platform. Now, Symbian OS is also used by a number of Japanese mobile manufacturers for handsets and sell inside of the Japan [31].

C. Comparison of the Smartphone Operating Systems

New generations of smartphone OSes have a lot of useful features which have led to more popularity and reputation among their users. We summarized some available features of smartphone OSes over the period of 2011-2017 that depicted in Tables 1 and 2. As a result, the majority of the users have preferred to buy Android OS smartphones due to having a lot of apps and open-source based software. Moreover, some famous companies such as Apple, Microsoft have lost many users due to they have closed source based apps and the high price of their products [35], [36], [39].

Table 2 depicts the percentage of global smartphone OS market share that has been sold to the end users (i.e., between the first quarter of 2011 to the end of first quarter of 2017).

As depicted in Fig. 5, almost more than 80% of the end users from all over the world have bought Android OS smartphones in recent years.

TABLE I. A COMPARISON OF THE SMARTPHONE OSES MARKET SHARE OVER THE PERIOD OF 2011 – 2017

Factors / OS Name	Android	Apple iOS	Windows Phone	BlackBerry (RIM)	Symbian and others
Source Code	Open source	Closed source	Closed source	Closed Source	Closed source, previously open source
OS Family	Linux	Unix-Like, Darwin	Windows NT	Unix-Like, QNX	RTOS
Support by	Google	Apple	Microsoft	Blackberry	Discontinued (2012)
Exclusive Company	Unexclusive	Apple	Unexclusive	BlackBerry	Unexclusive
Programming Written in	Java, C, C++, Basic	C, C++	C, C++	C, C++, Qt	C++
Smartphone Market share sold to the end users (%)	74.79 %	16.11 %	3.33 %	3.23 %	4.27 %

TABLE II. THE PERCENTAGE OF GLOBAL SMARTPHONE OS MARKET SHARE (USERS) [39]

Periodicity	Android	Apple iOS	Windows Phone	BlackBerry (RIM)	Symbian and others
2011	45.8	18.47	1.9	11.12	21.6
2012	65.85	19.125	2.45	5.17	6.85
2013	78.28	15.57	3.18	2.055	1.85
2014	80.97	15.1	2.82	0.65	0.47
2015	81.6	16.55	1.95	0.3	0.35
2016	84.95	14.27	0.5	0.17	0.17
2017	86.1	13.7	0.2		

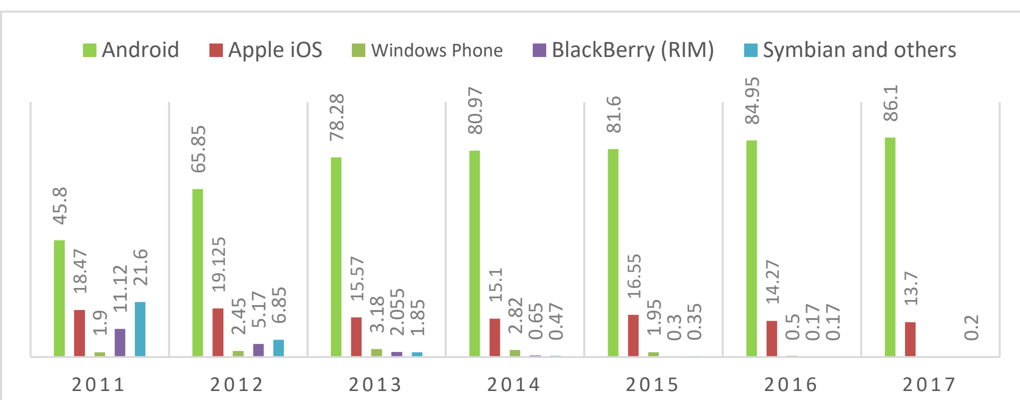

Fig. 5. Smartphones market share in sales to end users.

As already explained, Android OS allows developers to easily design apps with full permissions accesses such as data transfer, memory management, network management, etc. Currently, the huge number of Android OS usage and having open-source based apps have made those devices vulnerable encounter malicious users [40]. In other words, hackers can utilize reverse-engineering techniques to obtain sensitive information from the open-source apps and manipulate these apps for their malicious purposes [41]-[43].

III. Malicious Attacks

Nowadays, the smartphone users would like to download apps for different purposes including social networking, play new games, photography, etc. from app markets. In general, they do not care about the malicious of apps whether the downloaded apps are infected by malware or not and, in addition, they install them on their devices and run these apps. Due to these reasons, the number of infected smartphones by malware and adware apps are sharply growing as well. According to the latest report released by Kaspersky Lab [42], the number of malicious installation packages increased extremely in 2016, amounting to 8,526,221 three times over the previous year. As a comparison, from 2004 to 2013, they detected over 10 million malicious installation packages; in 2014 and 2015, the figures were 2.4 million and 2.96 million. However, the Android has some basic mechanisms to control the permissions of apps and the most important matter is that the wide number of unpredicted (or unknown) attacks are targeting smart gadgets, for example, if a malware app plays a role like a real app with logical permissions and hides some malicious activities in cover of its, then how the OS can detect whether it is malware or not. Obviously, it is essential that the users exploit a powerful anti-malware to mitigate those attacks. Further, based on the latest reports by the F-Secure and Kaspersky security teams which depicted in Fig. 6, the malicious attacks are still more than 84% over devices using Android OS [43]-[46].

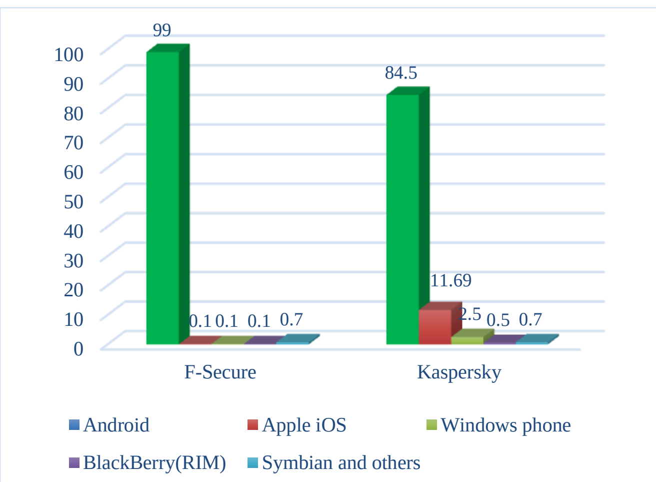

Fig. 6. Malware attacks on smartphone OSes.

In continue, we categorized software security issues on the smartphone OSes into three main branches including malicious software, vulnerabilities, attacks or threats, which are depicted in Fig. 7.

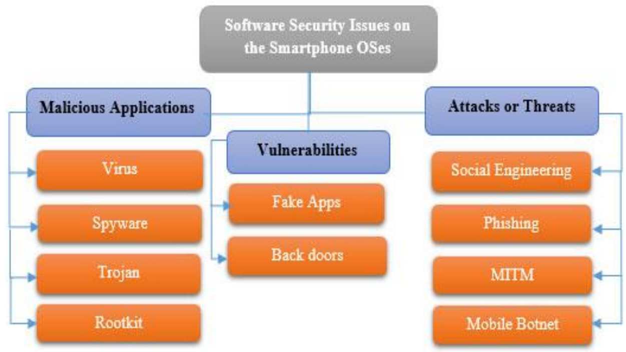

Fig. 7. Software security issues on smartphone OSes.

A. Malicious Applications

Mobile malicious application (MMA) is a hidden malware that can operate in the background of victim's smartphone completely imperceptible to the user, and in addition, it is available to execute or connect to other networks for getting new instructions. The MMA also can manipulate the victim's device and lead to gaining some results such as abusing sensitive account specs and information. For example, a MMA can send a message to the specific number or leak the user location without its knowledge [47]. In other words, the current version of the MMAs is becoming so much sophisticated with malware that can run in the cover of real apps, without any suspicions to the users and even anti-malware as well, then they can perform some trick activities under control of malicious users. The next generation of MMAs is predicted to be even more intelligent, with botnet tendencies to control and hijack victim's devices [48]-[50].

Malware: Basically, malware is a malicious software which may steal users' information from their devices and, in addition, the anti-malwares may predict their activities. Recently, there have been discovered numerous malicious apps that provide different vulnerable ways for the malicious attacks inside of the victim's device. In this case, the researchers categorize malware apps into four types which are detailed in the following points.

a) Virus is a malicious app that can imitate itself and the different imitations of a virus can infect other apps, boot sector, or files by attaching (or adding) themselves. In order to replicate the virus in victim's device, the infected app must be sent to the target device and performed by its user [1]. For example, in 2016, a specific virus has been discovered by check point team that infected over 85 million Android smartphones around the world. It was called 'HummingBad' and predicted that it could make money for its writers up to $300,000 per month [51].

b) Spyware is a malware which tracks victim's device for controlling user activities such as location, contacts, calls, texting, and emails etc. In some cases, it can send such information to another place via available networks (or e-mail, SMS, etc.) and take control over a device without the user's knowledge as well [52]. For example, Citizen Lab has discovered a new dangerous type of spyware in 2016, which was called "Surveillance" in Android and "Pegasus" in iOS.

This spyware was incredibly powerful and extremely effective that allowed hackers to take advantage for obtaining almost total control of the victim's device such as collecting email, monitoring call logs and monitoring messages, etc. [53].

c) Trojan is a kind of malware that provides unauthorized access to sensitive interactions of the users such as purchase transactions, premium rate calls, etc. in the background of the victim's device. Therefore, the goal of this kind of malicious apps is transmitting under the cover of real apps or files [1], [47]. For example, based on the latest report released by Tencent security researchers on February 2017 [54], they have disclosed a new banking Trojan which is named "Swearing". Further, this Trojan infected a wide spread of Android devices and stole bank credentials of their users and other sensitive information in China.

d) Rootkit is a hidden process that can run in the background of victim's device and build some malicious flaws by infecting the OS for malware writers. Practically, this malware tries to disable firewalls and anti-malware or conceals malicious user-space processes for installing Trojans [1]. For example, Gooligan is a kind of Rootkits which has been identified by Check Point on November 2016. Based on their technical report, a new attack campaign has breached the security of over one million Google accounts. This malware can expose messages, photos, documents and other sensitive data from the victim's device. In addition, it roots the infected device and snaffles authentication tokens which are required to hijack data from Google Play, Google Drive, Gmail, Google Docs, Google Photos, G Suite, and so on. The Gooligan potentially has infected Android devices on (Jelly Bean and KitKat) 4 and 5 (Lollipop), which it was included over 74% of devices in the market. About 57% of these devices were located in Asia and about 9% are in Europe [55].

B. Attacks or Threats

Attacks are intrusions or threats that are made by malicious programmers and, in addition, they use different vulnerable vectors in the target OSes (or apps) to take the control of the infected devices. All of these intrusions usually called attacks or threats, where they used to take control of the infected device via malware apps or vulnerabilities in the background of victim's smartphones. Commonly, they are made by malware writers for achieving access to sensitive information without the user's knowledge [56]-[58]. There are four main types of attacks including social engineering, phishing, MITM and mobile botnets.

a) Social engineering is a type of hidden trick for disclosing sensitive information, fraud or system's password, etc. This concept is a kind of hacking and involves maliciously abusing to obtain sensitive information that can be applied for malicious purposes. Sometimes, social engineers act as a confident and knowledgeable employee, such as managers or enforcers. In other situations, they may pose as outsiders, such as IT consultants, maintenance supporters, and native employees, etc. [59], [60]. In case of smartphones, social engineers usually take advantage from malicious advertising (Adware or "Malvertising"). There are many advertising markets (e.g. Google Ads, Apple iAd, etc.) that mobile developers can share their apps in the advertising markets in order to make revenue (e.g. amounting around $13 billion in 2013). The social engineers can also conceal their malicious codes in the cover of advertising apps for gaining their purposes. For example, The "TOR" browser was flooded a fake app in the Apple store that was able to run some advertising codes without user's permissions on March 2014 [61].

b) Phishing app is one of the malware which is designed exactly same as a real app (e.g., mobile banking app, market app, etc.) for stealing sensitive information such as usernames, passwords, credit card specs, etc. Technically, these fake apps pose like a real app by masquerading as a trustworthy app on the victim's device. The phishing apps can break the confidentiality of user input for hijacking login authentications. For example, a phishing app demonstrates a fake mobile banking login screen to steal the user's account information (e.g. username and password) [47], [60]. Mostly, it applied to hijack confidential information in the cover of fake mobile banking apps which have become a recurring threat according to several incidents reported. As a result of malware evaluation reported by Kaspersky Lab, there has been discovered amounting 128,886 mobile banking Trojans that have used phishing for hijacking the users' accounts information in 2016 [42].

c) Man-In-The-Middle (MITM) is a kind of stealthy fraud that strives to gain information by eavesdropping of data transmission between two devices when they communicate to each other. As shown in Fig. 8, the attacker makes a new connection between target device and server in a banking transaction. The hacker splits the direct connection into two new line by using different ways. The first connection is between hacker and server, another one is between victim's smartphone and hacker. This attack is one of the effective threats because of the property of the TCP and the HTTP protocols which are all Unicode or ASCII standard based. Therefore, the MITM hackers can decode and alter the data streams while they are passing through the target network [62], [63].

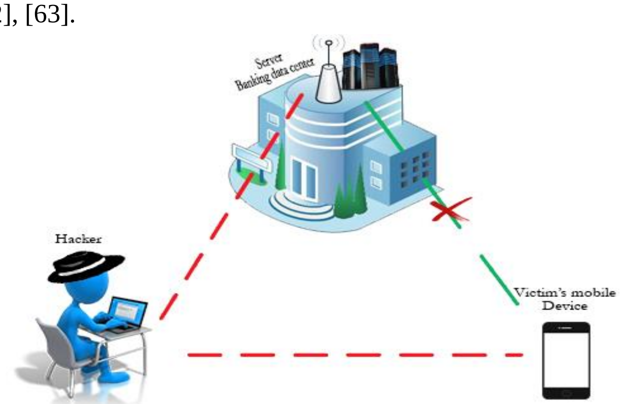

Fig. 8. An illustration of the MITM attack.

d) Mobile botnet refers to a group of infected smartphones which are remotely controlled by botmaster (e.g. a person who prevents the normal network traffic flow) without knowledge of the users. In other words, it provides a flaw inside of the intended app for taking complete access of the victim's device for attackers, and then begins contacting with it and getting new instructions from specific servers. From the hacking point of view, botnets are considered as one of the most dangerous types of attacks, which can be utilized and controlled for any type of malicious purposes (e.g. most commonly for DDoS (Distributed Denial of Service) or spam attacks) [64]-[66], [73]. For example, recently, the Check Point researchers have discovered a new strain of malware on the Google Play Store. This malware is called "FalseGuide" which was hidden in over 40 apps for guiding games and, in addition, the first version of this malware was shared on the Google Play in February 2017. The "FalseGuide" is able to generate a silent botnet out of the infected devices for adware or malicious purposes. In this case, several apps were manipulated to reach more than 50,000 installations and the number of infected devices was predicted to reach up to 2 million devices. Moreover, the Check Point informed the Google security team about this malware and they quickly removed it from the Google Play. At the beginning of the April 2017, two new fake apps were shared on the Google Play including this malware and the Check Point informed the Google security team once again [67], [72].

C. Software Vulnerabilities

In smartphone OS, vulnerability is a weakness or flaw that permits an attacker to break the security of smartphones. Technically, vulnerability is the meet of three bases: a device susceptibility or flaw, attacker ability to elicit the flaw, and accessibility of attacker to the flaw. There have been two reasons for increasing vulnerabilities on Android and iOS smartphones. Firstly, the Android is the most popular OS around the world, which is open-source software and moreover, there are a variety of security weaknesses in old versions of Android. In addition, most of the Android users do not care about updating new patches of the OS which may improve the security of their smartphones. Secondly, the users used to download apps from official app stores (e.g., Google Play, Apple Store, etc.) or third-party markets without checking the authenticity of apps and, then, they run downloaded apps on their devices. An attacker can apply these vulnerabilities by designing a malicious app (e.g. fake app, free app, adware app, etc.) so that it does not require to special permissions for taking advantage of these vulnerabilities. Generally, most of the users think that the Google Play and Apple Store are protected markets, so downloading apps from those markets are secure. But, this is a wrong viewpoint due to the malware apps like real apps, have specific contents and hackers usually conceal a malicious code in the cover of a real app for achieving their own profits [42], [47], [68]. As already pointed out, the Gooligan have been propagated from Google Play in the cover of free apps such as Prefect cleaner, Wi-Fi enhancer, Snake, Memory Booster and Stop watch, etc. [55]. As the results of our review, there are two main categories of vulnerabilities into smartphone OSes.

a) Free Applications: In this ever changing and evolving environment, a huge number of free apps are available on app markets in order to advertising or hijacking sensitive information from smartphone users. The question is "what are the benefits of sharing those apps with open access (or free)?", the first answer is, app developers release these apps for achieving popularity between users and the second answer is, the developers insert a cover code inside the fake app for gaining remote control or advertisements [42], [47], [68].

- *Adware apps:* Basically, this kind of free apps is not malware and used to release on the app stores for advertising via notification messages (or show advertising banners). Although, developers can hide a malicious code in the background of advertising apps.

- *Fake apps:* Malware writers usually design a fake app like a real app, but the difference is that the malware app somehow has the same or more permissions than a real app. For example, App 'A' is a music player in Android OS which may have access to the storages and the speakers of the device to run music files. As the results, if it has more access than these two permissions, then it will be suspected of being malicious.

b) Backdoor is a hidden flaw in the target OS (or software), which provides remote access to available networks for executing malicious attacks. Mobile backdoor is a set of hidden bugs or weaknesses in the background of smartphone OSes which make ideal resources for attackers. Moreover, the attackers can exploit these backdoor resources by using available data connection in the victim's device such as 3G, 4G, Wi-Fi, etc. without the user's knowledge [69], [70]. For example, Check Point and Kaspersky teams have identified a modular backdoor which targeted Android devices in 2016. In addition, the Check Point named this malware "Triada" which was granted Super-User privileges to download malware and infect the Zygote process (e.g. core process) through the Android OS [71]. This backdoor permits the malware app to run in the background of the infected device and changes the text messages while they are sending by other apps and, in addition, is able to steal sensitive information (e.g., banking credentials, personal data, etc.) from the victim's device [42].

IV. Most Wanted Mobile Malware Families

In this section, we summarized nine most wanted mobile malware families in details. As depicted in Table 3, we collected malware by focusing to the latest discovered installations in order to demonstrate the remaining issues of increasing mobile malware on the smartphones.

TABLE III. DETAILS OF MOST WANTED MOBILE MALWARE FAMILIES IN 2016-2017

Name	Discovered by	OS	Place of sharing	Installation Times (Infection)	Malicious Activities
Hummingbad	Check Point in 2016 [56]	Android And iOS	Google Play, Apple Store and other third party markets	+ 85,000,000	This Virus steals banking credentials and bypasses encrypted email containers used by enterprises.
Surveillance or Pegasus	Citizen Lab in 2016 [58]	Android and iOS	WeChat social media platform	It can infect all WeChat users	This Spyware allows hackers to control the victim's device for achieving sensitive information
Swearing	Tencent Researchers in 2017 [59]	Android	Third party markets in China	+ 100,000	This Trojan steals bank credentials of its users and other sensitive information
Gooligan	Check Point in 2016 [60]	Android	Google Play and other third party markets	+ 1,000,000	This Rootkit steals authentication tokens and provides data access from Google Play, Gmail, Google Photos, Google Drive, etc.
FalseGuide	Check Point in 2016 [71]	Android and iOS	Apple Store and Google Play	+ 2,000,000	This malware generates a silent botnet out of the victim's device for adware or malicious purposes.
Triada	Check Point and Kaspersky in 2016 [46], [75]	Android	Google Play and other third party markets	+ 100,000	This malware uses a backdoor to infect OS processes and provides a remote access for stealing money from users
Hiddad	Check Point and Kaspersky in 2016 [46], [75]	Android	Google Play and other third party markets	+ 2,000,000	This Trojan allows hackers to achieve sensitive user information
Ztorg	Kaspersky in 2016 [46]	Android	Google Play and other third party markets	+500,000	This Trojan installs some hidden apps and steals login credentials.
DressCode	Check Point in 2016 [76]	Android	Google Play and other third party markets	+2,000,000	This malware creates a botnet that uses IP addresses to generate false network traffics and makes revenue for the attackers.

Recently, a vast number of Spywares, Viruses, Trojans, and Rootkits that target the smartphones have been discovered. As we already mentioned, the reason for increasing the number of malware is the widely using of Android OS, and on the other hand, the users do not have enough knowledge about the malicious attacks. As the results, Apple iOS is becoming a fewer target for malicious attacks and, in addition, Android is the biggest target, both in terms of the number of users and open-source based platform which have caused it more vulnerable to malicious attacks [46], [56], [75].

V. SECURITY SOLUTIONS FOR SMARTPHONES

In this section, we overview some available mechanisms that are developed to prevent various types of software attacks or threats over the smartphones in recent years. In addition, we introduce existing malware detection techniques and, then present some countermeasures to mitigate malicious attacks.

A. Malware Detection Techniques

Basically, Android and iOS have provided some security mechanisms such as file access permissions, sandboxing, etc. to empower the security of their devices. However, due to growing the number of unpredictable attacks targeting smartphones, those defense mechanisms are not adequate to mitigate new malicious attacks [49]. As we have already explained, the number of malicious apps are extremely increased over 8 million in 2016, three times more than 2015 and have been stolen more than 100$ million around the world [42]. It is obvious that still, existing mechanisms are not able to identify new unknown malware and need to improve more against these attacks. From the malware detection point of view, the malware can be classified into two main categories: i) unknown malware: this is a kind of malicious apps which still is not discovered by anti-malwares or the security researchers, and ii) malware variant: this is a known malware with same behaviors and different interfaces (or skins), which is created by using repackaging techniques. The vast number of existing free apps are along with the unknown malicious codes, due to this reason the manual discovering of malware apps is a complex matter and somehow an impossible task for the cyber security analysts [49].

Recently, different techniques have been introduced for malware detection apps. The researchers classified malware detection techniques into two main categories: signature based and machine learning (or behavior detection) based techniques [13]-[16].

a) Signature based techniques: This is a kind of malware analysis techniques which works based on identifying specific patterns of known malware, which is called signature. In other words, signature based techniques produce a unique signature for a known malware, which can apply to detect the malware by comparing a newly identified signature with the database of signatures that have been previously built. The disadvantage of this technique is, if a malware writer makes a little change in the new version malware, then the signature will completely change and it may not be detected by use of this technique. To solve this challenge, the cyber security researchers have presented behavior detection or machine learning classifiers according to extracted features of apps during the dynamic and static analyses.

b) Machine learning based techniques: This kind of malware detection techniques utilizes machine-learning algorithms on the benign malware samples to generate the learning patterns, which can exploit for detecting both unpredicted (or new malware) and known malware. However, machine learning based techniques are more efficient than signature based techniques for identifying new malware due to their accuracies depend on the used features and the training set to produce the pattern through the static analyses. In case of dynamic analysis, the researchers utilize a machine learning (or deep learning) algorithms to extract features such that a set of malicious apps run in the OS either in a virtual or real device and, in addition, after running an app for a fixed period of time, the algorithm can produce some feature logs which are consisted the dynamic behaviors that occurred from the tested apps. Thus, these techniques could generate learning patterns with extracted features to detect malware during the running apps [17], [18].

In recent years, anti-malware companies have been proposed more powerful malware detection techniques for smartphones. These anti-malwares could provide high security more than basic mechanisms of smartphone OSes so that they utilize both (static and dynamic) detection techniques to identify new malware apps. For example, Kaspersky Lab registered nearly 40 million malicious attacks on smartphones and protected “4,018,234” specific users of Android devices in 2016 [42].

Table 4 includes eight top mobile security software and their features of 2017 which are released by the latest analyses of TopTenReviews [74]. To getting more details about the performance of these security software, we suggest readers to look at the TopTenReviews web site in [74].

B. *Countermeasures against Malware*

These days, the users used to think of malicious apps (or malware) only as a threat to personal computers and laptops. But as the most of the users moved to smartphones, cybercriminals are targeting these devices to a far greater extent. As we have already outlined, there are some challenges and vulnerabilities associated with mobile malware, how the users can reduce these issues by takingg control of their devices. In this section, we present seven security countermeasures for protecting smartphones and mitigating malware infections that help the users reduce those threats by focusing on them.

a) The users’ knowledge about Smartphones malicious risks

Most of the users do not realize a smartphone is similar to a computer and should protect it. As we have already pointed out, there are many fake apps (or adware apps) which are released on app markets. Practically, malware apps play a role like a real app (or adware app) in order to install and infect the target device by the users. Due to this reason, the users always should consider the source of apps (e.g. app, game, etc.). It is very difficult to distinguish whether an app is a malware or real, as well as, the difference of malware app and adware app is complicated, but there is a way to guess the malware app with more probability. In the Android OS, when a user wants to install an app (APK file), the OS shows a list of permissions and, therefore, the target app will have access to them on the device and user should approve the list to install it. For example, if an app asks for more permissions than what requires to perform its job, then, the user should not install it. It can be malware or adware apps [7], [20], [36].

As depicted in Fig. 9, while the app asks “it will get access to:” some permissions such as full network access, allow Wi-Fi Multicast reception and retrieve running apps, etc. which are not really required for a real video player installation. Therefore, the user should consider the actual requirements of the app and the permissions which are required to do its job.

b) Install apps from trusted sources

The users should only download and install apps from trusted app markets such as Apple Store and Google Play Store, etc. However, the users should also consider the developers of apps (or building enterprise on app stores). For example, when they want to download the apps or games, it is safe that select those ones with high ranks (5 stars) and good comments [11].

c) The security of wireless networks

Generally, wireless (e.g., Wi-Fi, 4G, 3G, etc.) networks are not protected, for example, if a user is connecting to a free Wi-Fi (data connection) at the airport, then the data connection may be exposed by hackers that are eavesdropping the wireless traffics on the same access point. The network designers must consider acceptable usage policies (e.g., VPN (virtual private network)), and it is essential that the users connect through a protected tunnel [47], [63].

d) Prevent Root (Android) and Jailbreaking (iOS)

Root is the process of adding a file in the Android OS that provides full access to the Linux kernel. When the users root an Android device, they actually add a standard Linux function that basically was removed. This function is a simple file which is called “Super-User” and it is located in the OS. In addition, it provides some permissions so that another user can perform (or remote access) it as well. It is considered for switching users and if the user performs an app, then it will switch the user’s permissions and credentials from a normal user to the Super-User.

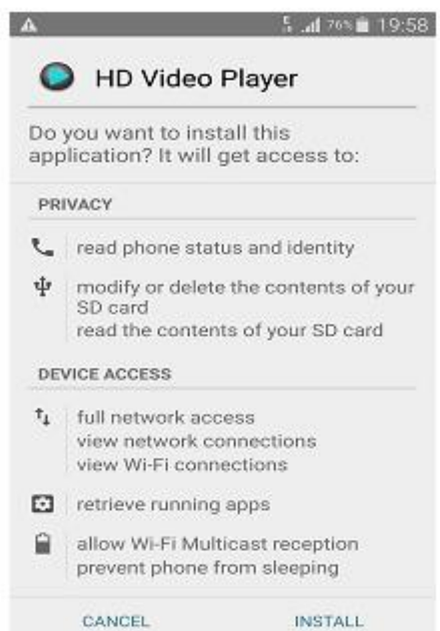

Fig. 9. An example of app permission access.

TABLE IV. THE BEST MOBILE SECURITY SOFTWARE OF 2017 [74]

Product	**Features**	**OS**	**License**
MacAfee Mobile Security [75] [66]	• Anti- phishing sites • Anti-malware • Anti-spam such as SMS, multimedia messages, etc. • Network monitoring • Anti-QR codes exploiting • Full data backup and restore	Android iOS BlackBerry Windows Phone	Commercial
Kaspersky Internet Security [76]	• Parental control • Anti-theft • Encryption • Anti-spam • Anti-malware • Real-time app analyzer • Firewall	Android iOS Windows Phone	Commercial
WebRoot Secure Anywhere [77]	• Malicious website blocker (Phishing infections) • Automatic app monitoring • Anti-spam (calls and messages) • Anti-malware • Detecting system flaws (e.g., devices and OSes backdoors)	Android iOS	Commercial
ESET Mobile Security [78]	• Anti-malware • Anti-spyware • Anti-spam (SMS-MMS) • App scanner before downloading into the device • It does not drain device battery	Android	Commercial
Bitdefender Mobile Security [79] [80]	• Anti-theft. • Anti-malware • Anti-spam • Lock Wipe from web • App scanner before downloading into the device • Remote security manager	Android iOS Windows Phone	Commercial
F-Secure Mobile Security [81]	• Anti-malware and anti-Spyware • Lock Wipe from Web • Anti-phishing • Anti-theft • Fill scanner before downloading into the device • Call & message blocker	Android iOS Windows	Commercial
Trend Micro Mobile Security [82]	• Malware scanner & malware cleaner • Fill scanner before downloading into the device • Anti-Spyware • Backup and restore on the offered online storage (up to 50MB) • Lost-device protection	Android iOS	Commercial
Lookout Mobile Security [83]	• Remote anti-theft • Anti-malware and anti-Spyware • Privacy of data • Calls & messages blocker • Full data backup and restore	Android iOS	Commercial

In continue, the user (i.e., with Super-User granted permissions) can have complete control on permissions and remove anything, add anything, access to the functions of the device, which the user could not reach before root it. For example, “Ztorg” is a malware which is used to infect the victim’s device by installing various hidden apps through the Super-User. It can steal login passwords and credentials on infected device [43]. Initially, Android does not have root access (e.g. there is no Super-User app in OS) because it provides full access to the system processes and increases criminal attacks. Jailbreaking is the act of removing the security limitations of the iOS which imposed by the vendor. This also means bypassing (or breaking) the security of iOS and permits all the apps including malware ones to access the data which assigned by other apps [1], [24]. The most important countermeasure against malicious attacks is that the users refuse to install ‘Root’ or ‘Jailbreaking’ on their devices.

e) Keep smartphone OS up to date

Generally, there are some limitations for updating the Android OS such that the updates can be blocked in a number of ways: by the manufacturers (which may consider some updates only for the latest models); by Google (which updates or improves security or errors in the OS); or by the network providers (which may not expand the bandwidth of their network to support updates). As the results, almost all the smartphone OSes have some errors and bugs, which without the ability to update, they are vulnerable to criminal attacks. The best advice is that the users check software updates of their devices periodically in order to receive the existing patches (e.g., improving security errors) [24].

f) Encrypt Smartphone

Losing a smartphone is one of the high-risk matters that may expose it to malicious attacks. It is obvious that the users should secure their devices by fully encrypting that makes it incredibly hard for someone to break or bypass the security and steal the sensitive information. It can be set by the pattern lock or a strong password for the device, even for the SIM card, is an important matter [24].

g) Encourage Smartphone Users to Install Mobile Security Software

Obviously, the infection risk of Android by malware is higher than iOS. The Google and Apple companies have taken preventive measures to prohibit malware in Android and iOS devices, but new attacks and sophisticated malware still have the effective impacts on these devices. As we already introduced, there are some trusted mobile security software that are able to protect the smartphones with high-security features such as anti-theft, anti-malware, anti-spam, etc. It is necessary that we encourage the users to use those security apps.

VI. Suggestions for the Future Works

In case of security and privacy, the smartphone users are not able to figure out the number of attacks on their devices and also how much money malicious apps may steal from their accounts. The duty of the researchers is that investigate about making clear security issues and announce to the users. There are still a huge number of malicious attacks, that are targeting smartphones more and more as mentioned in Section 3. As the results, most of the users do not use premium mobile security software and their devices are exposed as the ideal target for malware designers. In this survey, we outlined smartphones vulnerabilities, attacks and some trusted solutions for them. Due to the unpredictable growth of the malicious attacks with different types of techniques, it is obvious that this area needs to be drawn more by considering the following suggested points:

- The users usually download and install apps from the app markets and, moreover, they tend to know directly whether the app is included a malware or not, without concerning too much about the risk assessment.
- Technically, the malicious apps have various accesses to the OS processes in the background of fake apps that are utilized to infect the device. The researchers can investigate about the process monitoring and find a relation between app processes and output results in the fake apps. In addition, it can be used for the features extraction in OSes to announce the users about the risk of analyzed apps.
- Using new machine learning techniques for providing real-time behavior analysis and identifying fake apps.
- The network monitoring also can be used for the feature extraction in machine learning techniques, due to the malware apps exploit a network connection for transferring data to the hackers. For example, when the device is idle and an app is using a network connection, then it can suspect to be a malware.
- Deep learning algorithms can be utilized for the features extraction with more accuracy during the malware testing.
- The accuracy of the malware detection techniques still is not efficient to mitigate the huge number of malicious attacks.
- The Mobile OS companies, especially popular ones, should consider more security mechanisms for preventing against unpredictable attacks.

VII. Conclusion

With the rapid proliferation of the smartphone gadgets and developing apps with a lot of features, as several sensors and connections, the number of malware and attacks is raising. In the other hand, the diffusion of malware is increased due to lack of the users’ knowledge. Essentially, the users need more general awareness to reduce malware threats. In this survey, first of all, we have discussed different types of the smartphone OSes, malicious apps, software vulnerabilities and threats, by summarizing its evolution along with some highlight samples. Secondly, we have classified known attacks against smartphones OSes, especially at the application level, focusing on how the attack is executed and what is the target of the attackers. Finally, we have reviewed current possible solutions for the smartphone users by focusing on existing mechanisms, and then, we have suggested some future directions in order to improve this research area for the cyber security researchers.

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Factors Associated to Online Shopping at the BoP Community in Rural Bangladesh

Kazi Mozaher Hossein
Department of Advanced Information Technology
Kyushu University,
Fukuoka, Japan

Mariko Nishikitani
Institute of Decision Science for a Sustainable Society
Kyushu University,
Fukuoka, Japan

Hironobu Kitaoka
Toyota Motor Corporation
Aichi,
Japan

Fumihiko Yokota
Institute of Decision Science for a Sustainable Society
Kyushu University,
Fukuoka, Japan

Rafiqul Islam
Global Communication Center
Grameen Communications,
Dhaka, Bangladesh

Hiroshi Okajima
Toyota Motor Corporation
Aichi,
Japan

Akira Fukuda
Department of Advanced Information Technology
Kyushu University,
Fukuoka, Japan

Ashir Ahmed
Department of Advanced Information Technology
Kyushu University,
Fukuoka, Japan

***Abstract*—Online shopping is getting popular even in the rural areas of developing countries. However, few research has been conducted to identify the factors associated to online shopping by the poor villagers. Whereas people living at the bottom of the economic pyramid (BoP) has an aggregate purchase power which is a huge market and online shopping has the potentiality in reducing BoP penalty by removing unnecessary middlemen from the supply chain. In this research, we have conducted a field survey on 600 households in the western part of rural Bangladesh to find out current status of online shopping use by the BoP people and the demographic and behavioral factors associated with online shopping. Chi-square test of association and multi-variate logistic regression test have been performed to analyze data. Result shows that cell phone use, computer use, social media use, and mobile money transfer use have significant relationship in online shopping use at the BoP community.**

***Keywords*—Online shopping; BoP; demographic and behavioral factors; Bangladesh**

I. Introduction

Online shopping has been gaining acceptance rapidly due to the dot-com boom in the 90s globally [1]. The level of its acceptance and popularity has been growing since it has the potentiality to go beyond international boundaries enabling activities within the virtual marketplace. It has the flexibility of time and distance [2] in purchasing products. It provides wider product selection opportunity within limited space. Overall, it saves time, money and labor [3] of the consumers. Several studies on the usage of online shopping identified different factors, such as demographic factors, behavioral factors, infrastructural factors and so on [4]-[6]. Different studies identified the barriers of online shopping expansion globally [7], [8]. If we see the basic requirement of online shopping usage we find there are three major components to access online shopping such as; 1) Internet connectivity to access online catalog, 2) Payment mechanism such as credit card, mobile wallet etc. to make payment, and 3) Product delivery infrastructure [3].

However, these components are not equally ready everywhere in the world so that the consumers could get equal benefit from online shopping. Online shopping service primarily designed targeting the consumers at the top of the economic pyramid and gradually expanding towards the middle of the economic pyramid. Bottom of the economic pyramid (BoP) had been ignored. Currently, there are 4 billion people at the BoP, comprising 54% of the world population [9], [10]. Disposable income of the people in this segment is basically low [11] and shopping for daily needs is the norm and online shopping is not a priority. However, this scenario will change as more consumers continue to move up the socio-economic ladder.

Bangladesh, a developing country where online shopping usage continues at a rapid pace with recent growth of Internet usage, 3G roll-out in 2013 [12]. Mobile money transfer service replaced the need of credit or debit card as payment mechanism. Different product delivery companies are starting up to fulfill the need of online shopping product delivery. This infrastructural environment is increasing the use of online shopping and currently it is much popular in major urban areas in the country [13]. Although online shopping usage at the rural areas in Bangladesh is limited compared to the urban areas but it is expected to increase in the long run as we can see online shopping started to become popular in the rural areas of developing countries such as China and India [14]. Several researches have been conducted to identify the factors of online shopping. However, few research has been conducted to identify the factors associated to online shopping targeting the BoP community. This research is much important to the online shopping service providers so that they can design the service more efficiently after knowing the factors those affected behind online shopping decision making by the current online shopping users at the BoP community. Therefore, this research attempts to identify the factors that are primarily responsible behind online shopping by the BoP consumers. It aims to find the differences in socio-demographic and behavioral characteristics between low and high family expenditure groups of the online shopping users in BoP community.

Section II explains the motivation behind this research and Section III introduces the method of the experiment. Section IV describes the findings, Section V discusses the findings and Section VI concludes the article.

II. Research Motivation

This research started with a strong motivation to explore the existence and reasons of BoP penalty, and to design ICT based social services those can reduce the BoP penalty. The people at the BoP often pay higher prices for basic goods and services than do wealthier consumers [9]. Toyota Motor Corporation and Kyushu University in Japan are jointly carrying out a research and implemented in Bangladesh to see whether ICT and mobility could reduce BoP penalty or not since 2011. Grameen Communications in Bangladesh is supporting the experiment. A 10 seated Toyota Hiace vehicle is shared to carry ICT based 4 major services such as: 1) Remote healthcare; 2) Female friendly transport using car sharing model; 3) E-learning; and 4) Last mile delivery service of online purchase. This research project is known as Social Services on Wheels (SSW) [15]. Under SSW project there were two experimental sites in two districts in Bangladesh. One was in Kalihati Upazila under Tangail district (105 km away from the capital Dhaka city) and the other one was in Bheramara Upazila under Kushtia district (235 km away from the capital Dhaka city). In this research, we have used Bheramara Upazila as experimental platform. Bheramara is located in the western part of Bangladesh under Kushtia district and is close to the border of India. According to the census of Bangladesh Bureau of Statistics (BBS) 2011, the Bheramara sub-district has a population of 208,000 in six unions. We have found the existence of BoP penalty (Table I) from a baseline survey conducted in a rural area (Bheramara Upazila) and an urban area (Dhaka city). However, we argue that, online shopping can be used to reduce BoP penalty [3] as it has the potentiality to enable villagers to purch ase products from a village at any time of the day and get the desired products delivered to their doors. In this research we planned to explore current online shopping user status, online shopping use environment, and the factors that affected online shopping decision making in our experimental site.

TABLE I. PRACTICAL EXAMPLES OF BOP PENALTY

Item	Bheramara [Taka]	Dhaka [Taka]	Poverty Penalty [%]	Category
Mineral water (500 ml)	18	15	20	Food and Nutrition
Blood glucose test (1 time)	300	150	100	Healthcare
Rice (1 kg)	60	50	20	Food and Nutrition
LP gas cylinder (12 kg)	1000	800	25	Home appliance
Mosquito net (1 piece)	950	800	18.75	Healthcare
T-shirt (1 piece)	400	300	33.33	Clothing
Rickshaw fare (1 km)	15	20	(25)	Mobility
Paracetamol (1 tablet)	2	2	0	Healthcare
Soap (1 piece)	20	20	0	FMCG

III. Methodology

A. Data Source and Data Collection Procedures

We have conducted a field survey at one of the experimental sites of SSW project to collect data from community residents of Bheramara sub-district to identify online shopping user status, online shopping use environment, and the factors that affected behind online shopping decision making. The survey profile is mentioned in Table II below.

TABLE II. SURVEY PROFILE

Location	Bheramara sub-district, Kushtia district, Bangladesh
Duration	June 1 to June 15, 2016
Mode of interview	Face-to-face interview using semi-structured questionnaire
Type of sampling	Stratified random sampling
Sample size	600 households
Area covered during the survey	6 unions of Bheramara sub-district. 100 samples from each union

Participants were individuals from the rural households. Only one respondent was interviewed from one household. Three field staffs who had been working with SSW project were trained with a semi-structured questionnaire to collect data from the rural households.

B. Dependent and Independent Variables and Measurements

The outcome variable was online shopping use. Online shopping use was defined as online shopping experience by the respondents once in their lifetime and was classified dichotomously as "yes" or "no". All the independent variables (computer use, social media use, and mobile money transfer use) except cell phone user per family were dichotomously coded as "yes" or "no". Cell phone user per family was coded as "two or less (n≤2)" and "three or more (n≥3)" per family. Age, gender, employment status, education, and monthly family expenditure were selected as the main control variables. The households who had monthly family expenditure of 10000 taka or less belonged to low family expenditure group and the households who had more than 10000 taka as monthly family expenditure belonged to high family expenditure group.

C. Data Analysis

Socio-demographic and behavioral characteristics of the sample were analyzed separately by low family and high family expenditure groups (Table III). Pearson's chi-square test of association was performed to describe the unadjusted association between dependent and independent/control categorical variables (Table IV). Multiple logistic regression analysis was performed to describe the adjusted association of independent variables with the outcome variable online shopping use after adjusting with age, gender, employment status, education, and monthly family expenditure (Table V). Odds ratio (OR) and 95% confidence interval (95% CI) were calculated. Each independent variable was included in the logistic regression models separately because the independent variables were highly correlated (multi-collinearity). Thus, the following four distinct models were used considering one independent variable in one model:

Model 1: Logit Y1 (X) = β0 + β1 (age) + β2 (gender) + β3 (employment status) + β4 (education) + β5 (cell phone user per family) + ε

Model 2: Logit Y1 (X) = β0 + β1 (age) + β2 (gender) + β3 (employment status) + β4 (education) + β5 (computer use) + ε

Model 3: Logit Y1 (X) = β0 + β1 (age) + β2 (gender) + β3 (employment status) + β4 (education) + β5 (social media use) + ε

Model 4: Logit Y1 (X) = β0 + β1 (age) + β2 (gender) + β3 (employment status) + β4 (education) + β5 (mobile money transfer use) + ε

All statistical analyses were performed using SPSS version 22 (IBM Corp., Armonk, NY). A P-value <0.05 was considered significant.

IV. FINDINGS

Age range of the samples was from 15 to 80 years, and mean age was 37 (Table III). More than half (54%) of the samples were within the age-group of 15-39. Majority (79%) of the samples were male. A total of 35% of the samples were unemployed [N=558]. However, students and housewives were the major portion of the unemployed samples. Majority (86%) of the samples had high school level or less (up to grade 12) education [N=539]. 14% of the samples had higher education. In low family expenditure group, 7% people had higher education where it was 18% in high family expenditure group. 34% households had 3 or more cellphones. In high family expenditure group having 3 or more cellphones was more than double (43%) compared to the low family expenditure group (20%). 28% of the total samples reported as computer user which is almost 20% for low family expenditure group and 33% for high family expenditure group. One fifth (20%) of the respondents were social media user, 14% belonged to low family and 23% belonged to high family expenditure group. More than half (54%) of the respondents were mobile money transfer service user, 61% belonged to high family expenditure and 44% belonged to low family expenditure group. More than one-fifth (22%) of the respondents were known to online shopping, however, less than half of the respondents in low family expenditure group (12%) were known to online shopping compared to high family expenditure group (29%). Out of 587 respondents, 51 (9%) used online shopping. In low family expenditure group 6% respondents used online shopping and in high family expenditure group 11% respondents used online shopping.

Education showed a significant association (Table IV) with online shopping usage (P<0.001) in total and high family expenditure groups. However, in low family expenditure group the relationship was not significant (P=0.214). 21.1% of the respondent who had higher education used online shopping. On the other hand, 6.7% respondents who had up to 12 years of education used online shopping. Monthly family expenditure had a significant association (P<0.05) with online shopping usage. 5.9% respondents who had 10000 taka or less as monthly family expenditure used online shopping. Compared to that, almost double (11%) respondents used online shopping who had monthly family expenditure more than 10000 taka. Use of computer (P<0.001) had a significant association with online shopping usage. There was a significant relationship (P=0.024) between online shopping use and cell phone user per family. 16.2% respondents who had 3 or more cell phone users in their households used online shopping compared to 9.0% respondents who had 2 or less cell phone user. 22.2% of the computer user was online shopping user as well. More than double respondents used online shopping who belonged to high family expenditure computer user group (26.1%) compared to low family expenditure computer user group (12.8%). Use of social media (P<0.001) had a significant association with online shopping usage. 20.9% of the respondents used social media who were also online shopping user. More than double respondents used online shopping who belonged to high family expenditure social media user group (24.7%) compared to low family expenditure social media user group (11.8%). Mobile money transfer user (P<0.01) showed a significant association with online shopping usage. However, a border line association was found for low family expenditure group (P=0.091). 11.7% of mobile money transfer user used online shopping. Knowing online shopping showed a significant association with online shopping (P<0.01). However, for low and high family expenditure groups online shopping user percentage did not differ significantly (27.6% and 32.0% respectively).

TABLE III. SOCIO-DEMOGRAPHIC AND BEHAVIORAL CHARACTERISTICS OF THE SURVEYED SAMPLES COMPARING HIGH AND LOW FAMILY EXPENDITURE GROUPS

Items	**Total**		**Low family expenditure (≤10000 taka)**		**High family expenditure (>10000 taka)**	
	N	***%***	***N***	***%***	***N***	***%***
Age group	***N=587***	***Mean = 36.82 Range = 15-80***	***N=239***	***Mean = 33.21 Range = 15-73***	***N = 348***	***Mean = 39.29 Range = 15-80***
15-29 years	198	34.0	83	34.7	90	25.9
30-39 years	117	20.0	76	31.8	66	19.0
40-49 years	141	24.0	50	20.9	91	26.1
50-59 years	86	15.0	22	9.2	64	18.4
≥60 years	45	7.0	8	3.3	37	10.6
Gender	N=587		N=239		N=348	
Male	465	79.0	177	74.1	288	82.8
Female	122	21.0	62	25.9	60	17.2
Employment status	N=558		N=230		N=328	
Unemployed	197	35.0	96	41.8	101	30.8
Employed	361	65.0	134	58.2	227	69.2
Education	N=539		N=206		N=333	
≤Grade 12	463	85.9	191	92.7	272	81.7
>Grade 12	76	14.1	15	7.3	61	18.3
Cell phone user per family	N=587		N=239		N=348	
n≤2	389	66.3	192	80.3	197	56.6
n≥3	198	33.7	47	19.7	151	43.4
Computer use	N=587		N=239		N=348	
Yes	162	28.0	47	19.7	115	33.0
No	425	72.0	192	80.3	233	67.0
Social media use	N=587		N=239		N=348	
Yes	115	20.0	34	14.2	81	23.3
No	472	80.0	205	85.8	267	76.7
Mobile money transfer use	N=587		N=239		N=348	
Yes	316	54.0	104	43.5	212	60.9
No	271	46.0	135	56.5	136	39.1
Knowing online shopping	N=587		N=239		N=348	
Yes	129	22.0	29	12.1	100	28.7
No	458	78.0	210	87.9	248	71.3
Online shopping use	N=587		N=239		N=348	
Yes	51	9.0	14	5.9	37	10.6
No	536	91.0	225	94.1	311	89.4

TABLE IV. CHI-SQUARE TEST RESULTS OF DEPENDENT AND INDEPENDENT VARIABLES AND A COMPARISON BETWEEN HIGH AND LOW FAMILY EXPENDITURE GROUPS

Online shopping user (Yes, n=51)												
	Total				***Low family expenditure (≤10000 taka)***				***High family expenditure (>10000 taka)***			
Characteristics	***N***	***n***	***%***	***p-value***	***N***	***n***	***%***	***p-value***	***N***	***n***	***%***	***p-value***
Age group	N=587	n=51		0.173	N=239	n=14		0.067	N=348	n=37		0.221
15-29	220	24	10.9		99	9	9.1		99	13	13.1	
≥30	367	27	7.4		140	5	3.6		249	24	9.6	
Gender	N=587	n=51		0.277	N=239	n=14		0.514	348	37		0.086
Male	465	44	9.5		177	10	5.6		288	34	11.8	
Female	122	7	5.7		62	4	6.5		60	3	5.0	
Employment status	N=558	n=49		0.350	N=230	n=13		0.750	N=328	n=36		0.343
Unemployed	197	14	7.1		96	6	6.3		101	8	7.9	
Employed	361	35	9.7		134	7	5.2		227	28	12.3	
Education	N=539	n=47		<0.001	N=206	n=12		0.214	N=333	n=35		0.001
≤Grade 12	463	31	6.7		191	10	5.2		272	21	7.7	
>Grade 12	76	16	21.1		15	2	13.3		61	14	23.0	
Monthly family expenditure	N=575	n=51		<0.05								
≤10000	239	14	5.9									
>10000	336	37	11.0									
Cell phone user per family	N=587	n=51		0.024	N=239	n=14		0.036	N=348	n=37		<0.001
n≤2	389	19	9.0		192	8	4.2		197	11	5.6	
n≥3	198	32	16.2		47	6	12.8		151	26	17.2	
Computer use	N=587	n=51		<0.001	N=239	n=14		0.036	N=348	n=37		<0.001
Yes	162	36	22.2		47	6	12.8		115	30	26.1	
No	425	15	3.5		192	8	4.2		233	7	3.0	
Social media use	N=587	n=51		<0.001	N=239	n=14		0.120	N=348	n=37		<0.001
Yes	115	24	20.9		34	4	11.8		81	20	24.7	
No	472	27	5.7		205	10	4.9		267	17	6.4	
Mobile money transfer use	N=587	n=51		<0.01	N=239	n=14		0.091	N=348	n=37		0.036
Yes	316	37	11.7		104	9	8.7		212	28	13.2	
No	271	14	5.2		135	5	3.7		136	9	6.6	
Knowing online shopping	N=587	n=51		<0.01	N=239	n=14		<0.01	N=348	n=37		<0.01
Yes	129	40	31.0		29	8	27.6		100	32	32.0	
No	458	11	2.4		210	6	2.9		248	5	2.0	

Table V displays the results of Model 1 and 2 and Table VI displays the results of Model 3 and 4 of multivariate logistic regression analysis. Model 1 shows that participants who had 3 or more cell phone users in their households were 3.4 times more likely to use online shopping compared to the participants who had 2 or less cell phone users (OR = 3.41, P < 0.001) after adjusting age, gender, employment status, education, and monthly family expenditure. The multivariate results from Models 1–4 (Table V and VI) for online shopping use indicated that participants with cell phone use, computer use, social media use, and mobile money transfer use were significantly more likely to use online shopping (OR = 3.4, P < 0.001; OR = 6.2, P < 0.001; OR = 3.8, P < 0.001 AND OR = 2.1, P = 0.037, respectively) after adjusting for age, gender, employment status, education, and monthly family expenditure. The results of Model 2 for computer use indicated that the computer user are 6.2 times more likely to use online shopping compared to the non-user of computer (OR = 6.22, P < 0.001). The results of Model 3 for social media use indicated that social media user are 3.8 times more likely to use online shopping compared to the non-user of social media (OR = 3.78, P < 0.001). The results of Model 4 for mobile money transfer use indicated that the mobile money transfer user are 2.1 times more likely to use online shopping compared to the non-user of mobile money transfer service (OR = 2.13, P = 0.037).

TABLE V. AGE, GENDER, OCCUPATION, EDUCATION, AND FAMILY EXPENDITURE ADJUSTED ODDS RATIOS (ORS) AND 95% CONFIDENCE INTERVALS (95% CIS) FOR FACTORS ASSOCIATED WITH ONLINE SHOPPING USE (MODEL 1 & 2).

Model 1 (N = 512)					**Model 2 (N = 512)**		
		OR	**P**	**95% CI**	**OR**	**P**	**95% CI**
Age group	15-29	Ref					
	≥30	0.21	<0.001	0.09-0.53	0.31	0.012	0.12-0.77
Gender	Female	Ref					
	Male	1.17	0.761	0.39-3.34	1.10	0.858	0.37-3.11
Employment status	Un employed	Ref					
	Employed	3.59	0.016	1.27-10.26	2.43	0.093	0.86-6.91
Education	≤Grade 12	Ref					
	>Grade 12	3.34	0.001	1.57-6.89	2.43	0.020	1.12-5.10
Monthly family exp.	≤10000	Ref					
	>10000	1.43	0.357	0.68-3.13	1.44	0.347	0.69-3.15
Cell phone user per family	n≤2	Ref					
	n≥3	3.41	<0.001	1.76-6.79			
Computer use	No				Ref		
	Yes				6.22	<0.001	3.14-12.95

With regard to the age groups, Models 1–4 showed that the participants whose age were 30 or older were significantly less likely to use online shopping compared to those who were aged between 15 and 29 years (OR = 0.2, P < 0.001; OR = 0.3, P = 0.012; OR = 0.2, P < 0.001; OR = 0.2, P = 0.002, respectively). With regard to the employment status, Models 1, 3 and 4 showed a statistically significant relationship. The respondents who were employed were more likely to use online shopping compared to the respondents who were unemployed (OR = 3.6, P = 0.016; OR = 3.2, P = 0.024; OR = 3.0, P = 0.030, respectively). The employment status in Model 2 showed a border line relationship with online shopping use (OR = 2.4, P = 0.093). With regard to the education, Models 1–4 showed a statistically significant relationship. The respondents who had higher education (more than 12 years of education) were more likely to use online shopping compared to the respondents who had the education level high school or less (OR = 3.3, P = 0.001; OR = 2.4, P = 0.020; OR = 3.1, P = 0.002; OR = 3.4, P < 0.001, respectively). However, with regard to monthly family expenditure, Models 1–4 did not show statistically significant relationship with online shopping use after adjusting for age, gender, employment status, education, and monthly family expenditure.

TABLE VI. AGE, GENDER, OCCUPATION, EDUCATION, AND FAMILY EXPENDITURE ADJUSTED ODDS RATIOS (ORS) AND 95% CONFIDENCE INTERVALS (95% CIS) FOR FACTORS ASSOCIATED WITH ONLINE SHOPPING USE (MODEL 3 & 4)

		Model 3 (N = 512)			**Model 4 (N = 512)**		
		OR	**P**	**95% CI**	**OR**	**P**	**95% CI**
Age group	15-29	Ref.					
	≥30	0.22	<0.001	0.09-0.54	0.25	0.002	0.10-0.61
Gender	Female	Ref					
	Male	1.16	0.777	0.40-3.16	1.09	0.871	0.37-2.99
Employment status	Unemployed	Ref					
	Employed	3.17	0.024	1.16-8.68	3.04	0.030	1.10-8.41
Education	≤Grade 12	Ref					
	>Grade 12	3.12	0.002	1.47-6.43	3.39	<0.001	1.62-6.89
Monthly family exp.	≤10000	Ref					
	>10000	1.66	0.177	0.81-3.61	1.67	0.171	0.82-3.59
Social media use	No	Ref					
	Yes	3.78	<0.001	1.92-7.40			
Mobile money	No						
	Yes				2.13	0.037	1.07-4.50

V. DISCUSSION

This is the first study to investigate the relationships and factors associated with online shopping in the western region of rural Bangladesh as per the authors' knowledge. This study found 51 respondents (9%) out of 587 who had online shopping experience. The key finding was that online shopping use at the BoP community significantly associated with cell phone use, computer use, social media use, and mobile money transfer use after adjusting age, gender, employment status, education, and monthly family expenditure. Among them, computer use was the most significantly associated. Monthly family expenditure had a significant relationship before adjusting the variables. However, after adjusting with age, gender, employment status and education, it did not show significant relationship in all the four models in the analysis. This means, younger participants whose employment status was as employed and who had higher education showed a combined association with family expenditure to go for the decision of online shopping. Moreover, this research has found that, younger population (15-29 years old) were more likely to use online shopping compared to elderly population (more than 30 years old) at the BoP community. However, age group was not significant before adjusting the variables. The findings showed a similar trend in a study on global online shopping use trend where younger shoppers (21-34 years old) were the majority group [16]. The research did not find any significant relationship of online shopping with gender. However, findings on online shopping user status in Bangladesh showed that male were more likely to use online shopping compared to female [5]. The respondents who had higher education were more likely to use online shopping compared to the respondents who had the education of 12 years or less. The finding supports the online shopping use trend in developing countries [17]. This research has found a significant difference in the behavior of low family expenditure group and high family expenditure group for certain independent variables before adjusting with control variables. Education was significantly associated in high family expenditure group, but not in low family expenditure group. Similarly, social media use and mobile money transfer use were significantly associated with online shopping use in high family expenditure group; however, they were not significantly associated in low family expenditure group. Other independent variables such as cell phone user per family and computer use were significantly associated for both low family expenditure group and high family expenditure group.

VI. Conclusion

This study aimed to depict current online shopping user status and the factors associated with online shopping use in BoP community. From the literature survey it identified that online shopping has been getting popular especially in the top and middle of the economic pyramid. Bottom of the economic pyramid are lack behind to enjoy the benefit of online shopping. This research targeted to find out current online shopping user and associated factors believing online shopping could be applicable in reducing BoP penalty. It collected data from a BoP environment in rural Bangladesh and after analyzing the data it found current status and factors associated to online shopping. This research had limitations as it focused on socio-demographic and behavioral factors. As a future work this research aims to identify the psychological factors of online shopping in BoP community.

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Action Recognition using Key-Frame Features of Depth Sequence and ELM

Suolan Liu
Department of computer science
Changzhou University
Changzhou, China

Hongyuan Wang
Department of computer science
Changzhou University
Changzhou, China

***Abstract*—Recently, the rapid development of inexpensive RGB-D sensor, like Microsoft Kinect, provides adequate information for human action recognition. In this paper, a recognition algorithm is presented in which feature representation is generated by concatenating spatial features from human contour of key frames and temporal features from time difference information of a sequence. Then, an improved multi-hidden layers extreme learning machine is introduced as classifier. At last, we test our scheme on the public UTD-MHAD dataset from recognition accuracy and time consumption.**

***Keywords*—Action recognition; features; key frame; temporal; extreme learning machine**

I. Introduction

Action recognition has been a hot research topic due to its wild range of applications in many areas, such as intelligent video surveillance, smart living and human-computer interaction [1]-[3]. Although quite a lot of achievements have been reported in the latest several years, human action recognition still has great difficulties [4], [5]. Challenge mainly includes the high intra-class variability, e.g. one same action performed by different subjects and inter-class similarity of actions, e.g. different actions captured from one same person. These difficult issues constraint the further progress of vide technology based on RGB sequences [6], [7]. However, the release of Kinect sensor presents a new idea and more information to resolve these problems [8]-[10]. The Kinect sensor can provide high-resolution RGB images, depth maps and skeleton at same time. Compared with traditional color sequence, depth sequence is invariant and stable to the illumination and body appearance. Besides, it also provides body structure and shape information for action classification. Based on these advantages, many methods were proposed these years. In [11], Chen et al. projected depth images onto three orthogonal planes and a depth motion maps (DMMs) was produced by stacking these projected maps. Histogram of oriented gradients (HOG) [12] was then used as feature descriptor. Xia et al [13] detected STIPs from depth maps directly (called DSTIP) and then used a correction function to remove interest points resulting from noise. Further, for every DSTIP, they extract a depth cuboid similarity feature (DCSF). This feature is applied to describe the local 3D depth cuboid, which size is setting adaptable. Unlike using information only from depth sequences, there are some methods combing multiple information to do action recognition, such as color data, skeleton data and depth maps. Ni et al. [14] proposed two multimodality fusion methods, which is simply based on the concatenation of color and depth sequences. Moreover, two feature representation methods are introduced for action classification. Zhang et al. [15] extracted coarse depth-skeleton (DS) feature by utilizing gradient information from depth sequence and distance information from skeletal joints. To refine the coarse DS feature, they combine the sparse coding approach and max pooling method. Then, the Random Decision Forests (RDF) was used to classify different actions. Hsu et al. [16] introduced a new scheme by producing Spatio-Temporal Matrix Intensity (STMI) from raw RGB and Spatio-Temporal Matrix Depth (STMD) images from depth images respectively. This method was demonstrated to be view-invariant. HoG and HoF features were generated by constructing BoW-Pyramids, which made the classification of reversed actions become possible, such as from sit to stand and from stand to sit. Finally, the presented representation was applied to train a support-vector-machine (SVM) for recognizing different actions. Theoretically, the combination of different attributive data can effectively improve the recognition rate. However, the difficulties and disadvantages are negligible, such as features selection, different dimensional features fusion, training and testing times consumption, which has great relationship to judge the algorithm whether can be used on-line or not.

Inspired by the effectiveness of depth-based action recognition, in this paper we propose a novel algorithm for recognition using depth maps. To reduce calculating burden, key frames are produced from skeleton sequence by using joints as spatial-temporal interest points (STIPs) and mapped into depth sequence to represent an action sequence. Human contour is extracted from each key frame. Then feature representation is introduced including features obtained from human contour and temporal difference. Finally, an improved multi-hidden layers extreme learning machine is utilized as classifier for action recognition. The rest of the paper is organized as follows. In Section 2, we introduce key-frame extraction technique. Section 3 describes the proposed feature representation method. In Section 4, an improved method of multi-hidden layers extreme learning machine is presented for performing action recognition. In Section 5, the experimental results demonstrate the effectiveness of our framework from recognition accuracy and time consumption. Finally, we conclude our work in Section 6.

II. Key Frames Extraction

Key frames are usually used as the most informative frames because they can capture the major elements of a sequence. Key frame extraction approaches can be roughly divided into two categories: one is based on the interframe difference and the other is based on clustering [17], [18]. In the approaches of interframe difference, a new key-frame will be extracted if the interframe difference exceeds a setting threshold. Clustering-based approaches try to look for similar low-level features from frames and group them. Then a frame is selected as the key-frame, which locates closely to the cluster center [19], [20]. In this paper, considering skeleton provides detail body joint positions, so key frame extraction method based on distance difference accumulation is proposed. Define a joint position as $P_{i,j} = \{x_{i,j}, y_{i,j}, z_{i,j}\}$, i is frame index and j is joint index. The accumulated difference of the ith frame can be calculated as follows:

$$D_i = \sum_{j=1}^{n} \left\| P_{i,j} - P_{i-1,j} \right\|^2 \tag{1}$$

Where, $\|\ast\|$ and n denote the Euclidean distance and the number of skeletal joints, respectively.

Usually, the key frames are defined as the motion with maximum or minimum D_i within a sliding window. However, in most cases, D_i has low value in the first or last several frames or shows extremes in intervening time. As a result, the extracted key frames will be more centralized, and the sequence cannot be accurately and comprehensively expressed. Here we propose the following steps to address these issues:

1) For an action video with N frames, accumulate the total differences from the second frame to Nth frame and express as:

$$D_N = \sum_{i=2}^{N} D_i \ .$$

2) Set key frames number as K and calculate the average differences increment:

$$D_{avg} = D_N / K \, .$$

3) From the second frame to Lth frame, we calculate the difference:

$$W_L = D_L - k * D_{avg},\ k \in K \, .$$

We gain a set $\{W_L\}$ and the minimum value of this set on sth frame. So, the sth frame is the key frame.

The improved algorithm can effectively extract key frames to express the whole sequence. Key frame numbers are mapped to depth sequence and then human contour is extracted. A complete overview of the involved stages can be seen in Fig. 1. We select an action of 'draw circle (clockwise)' from UTD Multimodal Human Action Dataset (UTD-MHAD) as an example [21]. The first row of Fig. 1 shows the extracted six key frames from the skeleton sequence. The second row shows the corresponding depth images. In the third row, we list human contours based on the second row images. To facilitate the next step's feature representation, a treatment method with data smoothing and curve fitting is applied in the processing of contour extraction.

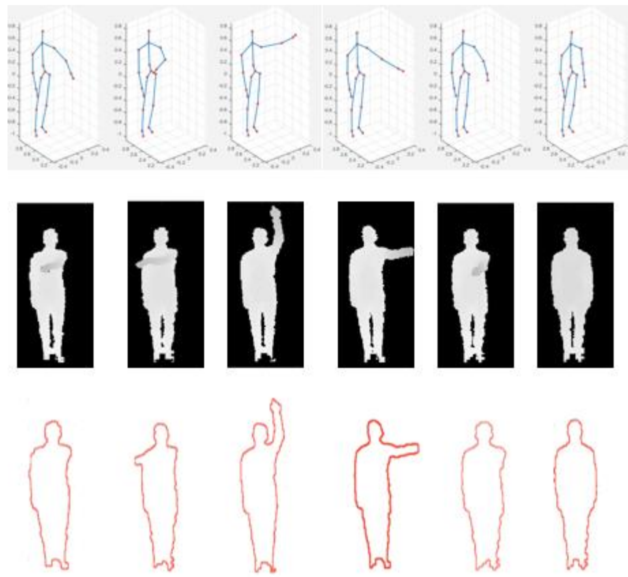

Fig. 1. Human contour based on key-frame extraction.

III. Feature Representation

To a contour with m points $CP = \{cp_1, cp_2, \cdots, cp_m\}$, the contour center $CP_c = (x_c, y_c)$ can be calculated with respect to the m number of points:

$$x_c = \frac{\sum_{i=1}^{m} x_m}{m}\ ,\quad y_c = \frac{\sum_{i=1}^{m} y_m}{m} \tag{2}$$

Take the center we can divide the contour into Q radial bins of the same angle. Then, based on the work in [22], [23] we extract features from contour. The point wise Euclidean distances between each contour point and the center of mass are calculated and recorded as $cp_i,\ \forall\, i \in \{1,\cdots,m\}$. Considering contour points should be in the same order, the corresponding bin q_i of each contour point CP_i is assigned as follows:

$$q_i = \begin{cases} \arccos\left(\frac{y_i - y_c}{cp_i}\right) \times \frac{180}{\pi} & \text{, if } x_i \geq 0 \\ 180 + \arccos\left(\frac{y_i - y_c}{cp_i}\right) \times \frac{180}{\pi} & \text{, else} \end{cases} \tag{3}$$

$$q_i = \left\lceil \frac{Q \cdot q_i}{360} \right\rceil \tag{4}$$

So, the feature vector of each bin can be described as:

$$\bar{v}_i = \frac{f(cp_k, \cdots cp_l)}{q_k, \cdots q_l} \tag{5}$$

$f(cp_k,\cdots cp_l)=\sum_{j=k}^{l}(cp_j-u_i)$ and u_i is the average distance of the contour points of bin q_i. Next, we concatenate Q bins features to form a feature V_k^d for the *k*th key frame image based on its contour, d is feature dimension.

However, by analyzing we find that some distinct activities may be very similar to each other on key frames. For example, two different activities of 'sit to stand' and 'stand to sit', the high similarity of key frames will lead to serious possibility of failure classification. Actually, they contain almost identical frames but different in time. So, we have to calculate time difference of key frames as temporal features, which can effectively help to distinguish different actions.

Assume kth key frame's original number in depth sequence is k'. The feature of kth key frame in previous work is V_k^d. The temporal difference of feature vector V_k^{td} can be defined as:

$$V_k^{td}=\begin{cases} V_{k'}^d & ,1\le k'<k_o \\ \dfrac{V_{k'}^d-V_{k'-k_o+1}^d}{\left\|V_{k'}^d-V_{k'-k_o+1}^d\right\|} & ,k_o\le k'\le N \end{cases} \tag{6}$$

k_o is the temporal offset parameter $1<k_o<N$.

The final features V of a key frame are concatenation of the spatial feature V_k^d and the temporal feature V_k^{td}, $V=[(V^d)^T(V^{td})^T]^T$.

IV. Action Recognition

Extreme learning machine (ELM) was proposed by Huang et al. [24], [25] as a novel learning algorithm, which is based on the single hidden layer feed forward neural networks (SLFNs). In ELM, the input weights and first hidden layer biases can be assigned randomly instead of learning. This advantage guaranties the learning and classification extremely fast and particularly suitable for online applications.

For N training samples (x_i,t_i), where $x_i=[x_{i1},x_{i2},\cdots,x_{in}]^T\in R^n$ and $t_i=[t_{i1},t_{i2},\cdots,t_{im}]^T\in R^m$. The standard SLFNs have Z hidden neurons. Then the activation function can be formulated as follows:

$$\sum_{i=1}^{Z}\beta_i g(w_i\cdot x_j+b_i)=o_j,\quad j=1,\cdots,N \tag{7}$$

$w_i=[w_{i1},w_{i2},\cdots,w_{in}]^T$ is used as weight vector, which connects the ith hidden neuron and the input. $\beta_i=[\beta_{i1},\beta_{i2},\cdots,\beta_{im}]^T$ is defined as the weight vector connecting the *i*th hidden node to the output nodes. b_i is applied as the bias term of the *i*th hidden neuron. If SLFNs can approximate the N samples with zero error, which means that $\sum_{j=1}^{Z}\left\|o_j-t_j\right\|=0,\quad j=1,\cdots,N$. There exist β_i, w_i and b_i such that $\sum_{i=1}^{Z}\beta_i g(w_i\cdot x_j+b_i)=t_j$.

It can be expressed as the following matrix calculation:

$$H\beta=T \tag{8}$$

Where, $H=\begin{bmatrix} h(x_1) \\ \vdots \\ h(x_n)\end{bmatrix}=\begin{bmatrix} g(x_1;w_1,b_1)\cdots g(x_1;w_Z,b_Z) \\ \vdots \quad \ddots \quad \vdots \\ g(x_n;w_1,b_1)\cdots g(x_n;w_Z,b_Z)\end{bmatrix}_{N\times Z}$.

There exists $\beta=\begin{bmatrix}\beta_1^T \\ \vdots \\ \beta_Z^T\end{bmatrix}_{Z\times m}$ and $T=\begin{bmatrix}t_1^T \\ \vdots \\ t_N^T\end{bmatrix}_{N\times m}$.

In ELM the input weight and bias are initialized and valued randomly, the output weight can be generated by solving the least square of β. In the condition where the number of hidden nodes is same with the number of input samples, the resulting H matrix will be square and invertible. But in actual applications, the number of hidden nodes is always not equal to the input samples, which makes H non-invertible. As a result, β can be formulated as finding a least squares solution $\hat{\beta}$.

$$\begin{aligned}&\left\|H(\mathrm{w}_1\cdots\mathrm{w}_Z,b_1\cdots b_Z)\hat{\beta}-T\right\| \\ &=\min_{\mathrm{w}_i,b_i,\beta_i}\left\|H(\mathrm{w}_1\cdots\mathrm{w}_Z,b_1\cdots b_Z)\beta-T\right\|\end{aligned} \tag{9}$$

To enhance the stability of the numerical solution of SLFNs, a regularization coefficient φ is given by considering the application of ridge regression method and Tikhonov regularization. The least-squares solution of (8) can be expressed as follows:

$$\hat{\beta}=H^T(HH^T+\varphi I)^{-1}T \tag{10}$$

Therefore, the output function of ELM can be expressed as $o(x)=g(x)\hat{\beta}$.

Let P_k^s denote the probability to an input sample x_s, whose output is o_k. d_j, $j=1,\cdots,Z$ is variable quantity of activation function of hidden layer nodes. Then, we construct a matrix W composed by w_i and $b_i, i=1,\cdots,Z$:

$$W=\begin{bmatrix} b_1 & b_2 & \cdots & b_Z \\ w_{11} & w_{12} & \cdots & w_{1z} \\ \vdots & \vdots & \ddots & \vdots \\ w_{n1} & w_{n2} & \cdots & w_{nZ}\end{bmatrix}_{n\times z} \tag{11}$$

So, P_k^s can be formulated as follows:

$$P_k^s = [w_{11},\cdots,w_{nZ},b_1,\cdots,b_Z,c_1,\cdots,c_n,d_1,\cdots,d_Z,j\ ]^T \quad (12)$$

$c_q \in \{0,1\}, q=1,\cdots,n$ is a binary variable. It is used to express an input reserved or not.

Multi-hidden layers ELM is a multilayer neural network based on extreme learning machine. It not only can approximate complicated function but also does not need iteration during the training process. It has much better generalization performance and processing rate.

For single hidden layer feed forward neural network, the activation function usually defined as a sigmoidal function. But for multi-hidden layers ELM, we define the activation functions as follows:

$$g(x_i;w_j;b_j)=\begin{cases}0 & , d_j=0\\ 1/\left(1+\exp(-(w_j\cdot x_i+b_j))\right) & , d_j=1\\ w_j\cdot x_i+b_j & , \text{else}\end{cases} \quad (13)$$

Once P_k^s is calculated, the next formulation is used to discriminate the final classification of an input:

$$C_k(x_s)=\max_k\{P_k^s\} \quad (14)$$

V. Experimental Results and Analysis

In this section, we test our proposed action recognition scheme on the public UTD-MHAD [21] dataset that consists of depth sequences and skeleton data. Our method is then compared with some existing methods.

A. UTD-MHAD Dataset and Tests Setting

The dataset records 27 different actions performed by 8 persons (4 females and 4 males). Each subject repeated each action 4 times. The subjects were required to face a Kinect during the performance. The same experimental settings as reported in [26] are followed in our tests. 20 actions are divided into three subsets as illustrated in Table 1. In test one, half of the action samples are utilized for training and the rest for testing; in test two, 3/4 action samples are applied as training samples; and in the cross subject test, half of the subjects including 1,3,5,7 are applied as training samples and the rest subjects are used for testing.

B. Comparison with Other Methods

In order to evaluate the effectiveness of approach proposed in this paper, our method is compared with the existing methods and the obtained classification accuracies are recorded. Three algorithms are selected: first, algorithm from literature [13]. In this method spatio-temporal information and depth cuboid similarity feature (DCSF) are used. Then bag-of-words is presented for classification. Second, algorithm reported in [27]. A depth motion maps (DMM)-based human action recognition method using l2-regularized collaborative representation classifier is introduced. Third, method in [28] skeleton joint position information with temporal difference is produced as final feature, and extreme learning machine is used for action recognition. The comparison results are listed in Table 2. The best recognition results are highlighted in bold. By comparison, it can be seen that our scheme outperforms the approaches published in [13] in all three test cases. For the challenging cross subject test, algorithm in [28] produces better results on AS2 and AS3. The most probable reason for this may be that actions in the two subsets are more complicated and the proposed accurate joint position information can effectively solve the problems of high intra-class variability and inter-class similarity. In test one and test two, only on action set 1 our results are slightly lower than C Chen's method [27] from 0.3% to 0.6%, while our method shows highest recognition rate in the overall results.

TABLE I. Three Subsets of UTD-MHAD Dataset

Action Set 1 (AS1)	**Action Set 2 (AS2)**	**Action Set 3 (AS3)**
1. right arm swipe to the left 2. right arm swipe to the right 3. right hand wave 5. right arm throw 8.right hand draw x 9. right hand draw circle (clockwise) 10. right hand draw circle (counter clockwise) 11. draw triangle 19. right hand knock on door 20. right hand catch an object	4. two hand front clap 6. cross arms in the chest 7. basketball shoot 13. front boxing 14. baseball swing from right 15. tennis right hand forehand swing 16. arm curl (two arms) 17. tennis serve 18. two hand push	12. bowling (right hand) 21. right hand pick up and throw 22. jogging in place 23. walking in place 24. sit to stand 25. stand to sit 26. forward lunge (left foot forward) 27. squat (two arms stretch out)

TABLE II. Recognition accuracies(%) of Different tests

		X Lu et al. [13]	**C Chen et al. [27]**	**X Chen et al. [28]**	**Our method**
Test One	AS1	91.1	**95.0**	87.4	94.7
	AS2	87.3	91.4	86.2	**92.8**
	AS3	90.5	93.6	89.1	**94.1**
	Average	89.6	93.3	87.6	**93.9**
Test Two	AS1	91.6	**98.7**	89.1	98.1
	AS2	91.3	93.4	90.5	**95.2**
	AS3	92.5	99.3	91.0	**100**
	Average	91.8	97.1	90.2	**97.8**
Cross Subject Test	AS1	86.4	90.6	73.8	**91.9**
	AS2	72.3	82.7	**87.6**	81.5
	AS3	78.1	83.4	**86.2**	79.3
	Average	78.9	**85.6**	82.5	84.2

The real-time efficiency of the proposed scheme is further discussed and reported. There are three major processing components including key frames computation, features extraction and fusion, and classification. In Table 3, we list the average time needs of each component for the UTD-MHAD dataset. All the experiments are carried out using MATLAB on a PC equipped with Intel Xeon 3.4 GHz CPU with 16 GB

RAM [29]. From the report in Table 3 we can find that the proposed scheme can be applied on a real-time depth video processing which requires the processing rate to be not less than 30 frames per second.

TABLE III. PROCESSING TIMES ASSOCIATED WITH THE COMPONENTS OF OUR METHOD

Action classification	Average processing time (ms/frame)
Key frames extraction	2.3
Features extraction and fusion	6.4
Classification	13.7

VI. CONCLUSION

In this work, we present an action recognition scheme for Kinect captured data. We extract features from human contour of key frame from depth sequence and calculating temporal difference as constraint. We use an improved multi-hidden layers extreme learning machines as the classifier for its high classification accuracy and low time consumption. Experimental results indicate that the proposed features not only can be easily obtained but also provide distinctive information for classification. To further expand our work, we plan to conduct some experiments involved human-human interactions by using method proposed in this paper.

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Development of a Mobile GIS Property Mapping Application using Mobile Cloud Computing

Victor Neene
Department of Computer Science
University of Zambia
Lusaka, Zambia

Monde Kabemba
Department of Computer Science
University of Zambia
Lusaka, Zambia

***Abstract*—This study presents the development of a mobile GIS Property mapping application for use by local authorities in developing countries. Attempts to develop property mapping applications especially in developing countries have mostly used GIS desktop productivity software tools that required the digitization of property maps by highly skilled GIS experts. In addition, these applications lacked real time capture of attribute, spatial and image data of properties. A survey was conducted in the Kafue local authority to gather systems requirements for the mobile application. After design and modeling, the developed application was trialed in the field and 10 properties were mapped successfully. The software tools used in this study included Android Studio, Leaflet mapping library, Apache2 web server, PostgresSQL with PostGIS Extensions and OpenstreetMaps and MapBox mobile cloud computing mapping services. The hardware tools used included a laptop computer and a mobile phone running android operating system. The study showed that mobile property mapping applications can be developed by tapping into the computing resources provided by mobile cloud computing. The benefits of this model include real time complete property data capture and the use of non GIS experts in mapping projects.**

***Keywords*—Leaflet; MapBox; mobile cloud computing; OpenstreetMaps; property mapping**

I. Introduction

Property mapping is very important because local authorities generate revenue from properties. The revenue that is generated is utilized on the provision of basic services, infrastructure development and maintenance of infrastructure within the jurisdiction of the local authority. Despite the benefits that would accrue to local authorities through the collection of property taxes, it still only makes a small contribution of 0.5 percent to the GDP in Sub-Saharan Africa compared to a contribution of 2 percent in the developed world [1]. The small contribution to the GDP in Sub-Saharan Africa is attributed to paper based property databases that local authorities maintain. These databases do not substantially help in the process of identification of properties because they do not have the required geographical information on the properties that are physically on the ground [2]. The property databases also in most cases do not have street names of the residential areas. This has resulted in the failure by the local Authorities to locate the properties for purposes of bill delivery either physically or through the public postal office system. In addition, follow-ups to residents that have defaulted on tax payments have proved to be a very daunting task [3]. The other challenge pertains to the update of the maps that show the geographical locations of the properties that are captured in the property databases. This problem has been exacerbated by the high number of properties that are being developed [4].

In this study, we develop a field based mobile GIS property mapping application to help the local authorities overcome challenges of property identification and capture. We begin by first reviewing the literature on the existing technologies and the related applications that have been developed. We then proceed to discuss the materials and methodology used in the study after which we describe how the application works. A discussion on the design and modeling then follows. We then compare our application with related applications before we discuss the work and then conclude.

II. Literature Review

A. Mobile Cloud Computing

Applications developed for mobile devices are increasingly becoming abundant because mobile computing has provided tools to users for utilization wherever they are and whenever they want to use them irrespective of their geographical position [5]. Examples of applications that have emerged include m-commerce, m-learning, m-healthcare, m-travelling and m-GIS applications [6]. This mobility has created a resource constraint for mobile devices because they were designed with limited computing, storage and energy resources [7]. The solution to this problem has been provided by mobile cloud computing technology which is an amalgamation of mobile computing and cloud computing. Cloud computing depends on the sharing of network resources to attain a high availability of computing resources and it helps in reducing management and economic costs. It is facilitated by hardware virtualization technology, parallel computing, distributed computing and web services [8]. Applications are delivered as services on the internet and are provided by shared hardware and software systems in very large data centers. This model ensures that computing resources are offloaded from the mobile device and are in turn provided as pay as you go and on demand services [5].

B. Leaflet, GeoJSON and OpenStreetMaps

The Leaflet mapping Library and GeoJSON objects are some of the tools that can be used to build mobile GIS Cloud Computing applications. The Leaflet Mapping Library is an opensource JavaScript Mapping Library that is used for mobile friendly interactive maps. It has a very small JavaScript code footprint of only 38Kb and it has most of the mapping features that developers require for use in their mobile mapping application projects. It works on almost all the existing desktop and mobile platforms and it is scalable through the use of plugins. It is also used for rendering vector and raster maps such as OpenStreetMaps and MapBox respectively [9]. GeoJSON objects are geographical data formats coded in JavaScript Object Notation (JSON) that are used for encoding different geographic data structures. The geographic structures include point, polygon, multipoint, multistring and multipolygon geometries [10]. OpenStreetMaps are free vector maps that are being constructed by mapping volunteers around the globe. The OpenstreetMap (OSM) project was started because geographical data is not provided for free in many parts of the world. The affordable GPS units embedded in mobile devices have facilitated the voluntary creation of free vector maps by mapping volunteers around the world [11]. OSM is sometimes referred to as the Wikipedia of maps because the project facilities distributed work around a common product (maps). Its database contains geographic data for many parts of the world. Its website has a set of software tools that enables registered users to contribute to, download, or otherwise interact with the spatial database [12]. The most common method used to record spatial data is through a GPS receiver and the spatial data is later edited using the freely available editors. Additional information about the collected spatial data is added by supplying attribute data and storing the final data set in the OSM database [13].

C. Related Works

In the USA, Rutgers University developed an offline vacant property mapping application that used a smartphone running ArcGIS collector as the front end and ArcGIS desktop as the backend. The backend and the frontend were linked using ArcGIS online (AGOL) that provided the map data. Primary attribute and spatial data was collected offline and later synchronized because of budget limitations [14]. In Ghana, Martey and Tagoe developed a GIS based Property Information System (GPTIS). GPTIS was developed to help in the administration of Property Tax through the use of a digital Map that showed the properties in the Municipality. It was developed for Tarkwa Nsuaem Municipal Assembly (TNMA). GPTIS was programmed using the .NET development framework and Visual Basic was used as the programming Language. The Map Object Library developed by the Environmental Systems Research Institute Inc(ESRI) was used to provide Mapping functions. MapBox Earth API's were also used. The Backend for data storage used shape data files, image files and Microsoft Access Database. GPTIS interface allowed users to perform spatial and non-spatial queries, update of newly registered properties, update and processing of property attribute data. Spatial data was obtained by digitizing the Map of the study area and GIS software was used to geo-reference the Map. Non Spatial Attribute Data was entered through the user interface. GPTIS was designed as a standalone application with limited remote access features [15].

In Nigeria Oluwadare and Ojo used GIS in Olorunda Local Government Authority to determine the geographical location of each property with the associated property attribute data to help in the effective collection of tenement rates (property taxes). Spatial data was collected using a GPS receiver device on 85 parcels of land in Orolanda Local Government Authority. Satellite imagery of the area was downloaded from MapBox Earth software application. The Satellite image was then digitized into vector Maps using Corel Draw 11 and ILWIS 3.0 environment for georeferencing software applications. The final digitized map layers were then exported to ArcView 3.2a software. Property attribute data and GPS co-ordinates were input in a Microsoft Access Database and then linked with ArcView GIS. The GPS dataset helped in determining the shape and size of the property land parcels [16]. In Oluyole local Government Area of Oyo state Nigeria, a land information system was developed to map properties. Spatial data was acquired through the digitization and geo-referencing of the hard copy layout plan of the area. Attribute data was obtained through a social survey on the ground. ArcGIS desktop GIS were used both as a front end and a backend [17].

In Sri Lanka, an Integrated Geographical Buffering System (IGBS) was developed by for use to value land parcels for the purposes of property Taxation in the Gampola region in Kandy District in the Central Province of Sri Lanka. A high resolution satellite image of the area was digitised using ArcView GIS Version 3.1. A hand held GPS Receiver Device (Geo Explora XT) was used to assign co-ordinates on the image of the location of interest. IGBS features included acquisition, storage and retrieval of valuation and taxation information about the land, compilation of complete tax records, graphical display of spatial data, analysis and processing of meaningful land valuation [18]. In Mexico, Bently federated GIS developed the Cancun Federated Geospatial Information System so that Property Tax Collection Revenues could be increased. Ariel Photography was used to capture the Image of Cancun Municipality. Mobile hand held GPS devices where used to capture Geo-Coordinates, property attribute data and images of the property. The property spatial and attribute data was subsequently integrated into a single map desktop GIS. The GIS system allowed the update of property information, discovery of properties with new development, entering, recording and production of property tax records. The GIS database was centralized and was accessible by other departments within Cancun Municipality [19]. In China, a Service Oriented GIS based Web Application was developed by Yang et al. to provide information on land and the corresponding prices in Feng County in the Jiangsu Province of the People's Republic of China. The Latest city maps of Feng County were digitized using ArcGIS and later uploaded to a Server. SQL Server 2008 was used as the main Relational Database Management Systems and ArcSDE and ADO.NET were used as communication tools between the business logic tier and data tier. This was done to facilitate management of spatial and attribute data in SQL Server 2008. ArcGIS server was used to display, query and analyze land prices. The features of the GIS based Web Application included, map frame for viewing of spatial land price Information, Zoom in/out, map printing, document download, upload of new data sets of spatial and attribute data [20].

III. Materials

The materials used in this study included hardware and software tools. The hardware included an Asus Laptop Computer and a Huawei G630 mobile phone. The software included Android Studio 1.3.2, PostgresSQL version 9.3 with PostGIS extensions, Apache2 version 2.4.7, the Leaflet Mapping Library version 0.7.7, jquery and OpenStreetMaps and MapBox mobile cloud computing services. Table 1 gives the specifications of the hardware tools that were used in the study.

TABLE I. HARDWARE TOOLS SPECIFICATIONS

Hardware	**Specifications**
Asus Laptop	• 1TB HDD • 5th gen Intel Core i5 processor 2.2 GHz with Burst Frequency up to 2.7 GHz • 8GB of RAM clocked at 1,600MHz • 2GB Nvidia GeForce 920M • 366 x 768 pixel resolution • 64 bit Operating System
Huawei G630 Mobile Phone	• GSM/HSPA Network • 720 x 1280 pixels (~294 ppi pixel density) • Quad-core 1.2 GHz Cortex-A7 • 4 GB, 1 GB RAM • Camera - Geo-tagging,8 MP Back , 1 MP front, autofocus, LED flash • GPS with A-GPS • Android 4.3 • microSD, up to 32 GB (dedicated slot)

IV. Methodology

The study used the agile software development methodology. The mobile application system requirements for the study were formulated from the survey that was conducted at Kafue local authority and from secondary sources in the literature. The survey used questionnaires and interviews to inform the design of the mobile mapping application. Before the property mapping commenced, the trial mapping area was mapped by using the embedded GPS unit of the mobile phone and OpenStreetMap mapping tools to include roads and points of interest. More than five days later, the changes become visible on the global OpenStreetMap vector maps. The mapping of roads facilitated the smooth mapping of property land parcels. The developed mobile application was trialed in the Parkview Estates of Kafue local authority. The attribute, spatial and image data was captured in real time on the ground from residents after consent was obtained to have their properties mapped. The property data was stored on the laptop computer. Ten properties were successfully mapped. Spatial data was obtained using a combination of MapBox raster maps and the Mobile Device's GPS unit in conjunction with OpenStreetMaps vector maps from the mobile cloud computing services. The mobile device's Internet speed and the saving of the property attribute, spatial and image data on the laptop using the phone’s WIFI (802.11 b/g/n) did not manifest any adverse latency during the mapping sessions. The latency was less than 100 milliseconds (0.10 seconds) on average.

V. Operation and Use of the Mobile GIS Property Mapping Application

This section describes how the implemented mobile GIS application is operated and used. The first task in the property mapping process involves the capture of the property attribute data which includes the capture of owner, land and property details. The second task involves the capture of spatial data and property image data.

A. How to Capture Attribute Data

Property attribute data capture is carried out in three stages using three different screens. The first screen that is used is shown in Fig. 1. This screen captures details that pertain to the property owner. Validation checks are performed to ensure that data is entered correctly and that all mandatory fields are not left blank. When the create button is clicked the property owner record is saved in the PostgresSQL database and a unique owner identity number is generated.

Fig. 1. Property owner details capture screen.

Fig. 2 shows the screen that is used to capture land attribute data. When a valid Owner Identity Number is entered and focus moves to the next field, property owner names and national registration card number (NRC) are retrieved. The rest of the fields from the land use type to ward require the user to fill them manually. As data is entered in the fields, appropriate validation and mandatory checks are done. When the create button is clicked, the land record is created and a unique land identity number is generated.

Fig. 3 shows the property details screen that is used to capture property (building) attribute data. When a valid owner identity number is entered in the owner id field, details from the owner record and from the associated land record are retrieved. Property Descriptions, year constructed and building use data fields are entered manually by the user. As the data fields are filled, validation and mandatory field checks are done.

Fig. 2. Land details capture screen.

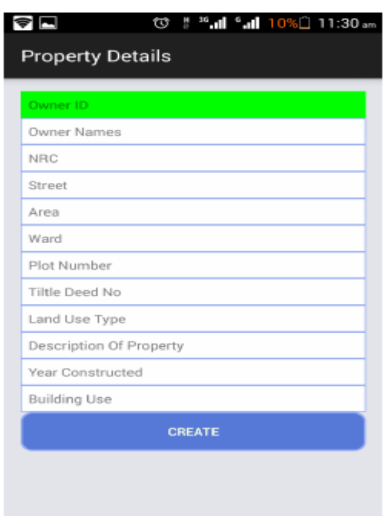


Fig. 3. Property details capture screen.

B. How to Capture Spatial and Image Data

Fig. 4 and 5 shows the first and second tabs of the property mapping screens, respectively. The first tab is used to retrieve owner property details as shown. The second tab is used to select the property mapping mode and also to capture images of the property.

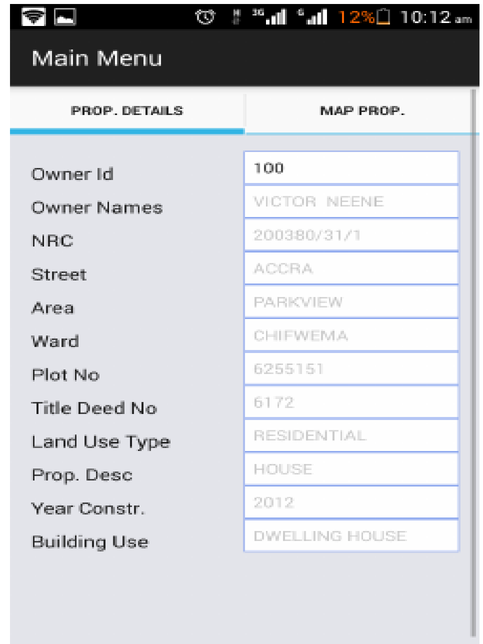


Fig. 4. First tab.

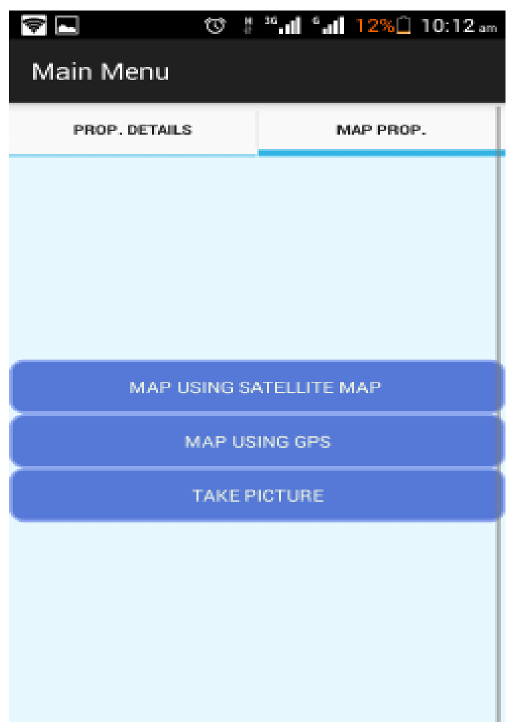


Fig. 5. Second tab.

Fig. 6 shows the MapBox satellite image of the property mapping area when the Map Using Satellite Map option is selected. The mapper zooms in on the property using the (+) zoom icon. When the property is located, the mapper uses the line tool bar to draw the land parcel as shown. When the Finish menu item is clicked, the GPS coordinates represented by the white squares are then saved to the database and an appropriate message is displayed.

Fig. 7 shows the screen for the Map Using GPS option. The GPS Blue Marker, shown is displayed for ten seconds. As the mapper moves around, the marker also moves. When the approximate visual position of the GPS marker is on an approximate beacon location as guided by the underlying OpenStreetMap roads, a white square is placed on top of the marker to capture the GPS coordinates. This process is repeated for all the beacons. When the finish menu item is clicked, the GPS coordinates represented by the white squares are then saved to the database and an appropriate message is displayed.

The take picture function invokes the mobile device camera to enable the mapper take pictures of the property. A picture is transmitted to the webserver for storage immediately it is taken. The application allows the mapper to take as many pictures as possible.

C. How to View Mapped Properties

Fig. 8 and 9 shows the list of properties and an overview of land parcels respectively when captured during the property mapping Exercise.

Fig. 10 shows the Mapped Land Parcels and the Pictures of the Property when mapped. When the Land parcel is tapped on the map, details of the property are displayed as shown. Clicking on the view photos of the property link displays the pictures of the property that are captured during a mapping exercise as shown in Fig. 11.

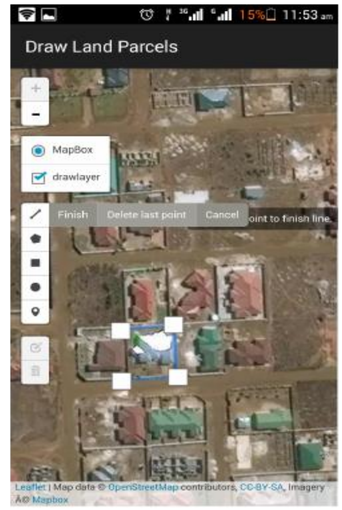


Fig. 6. Mapping using the MapBox Satellite Image.

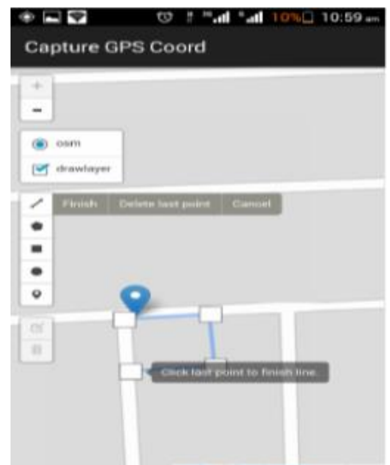
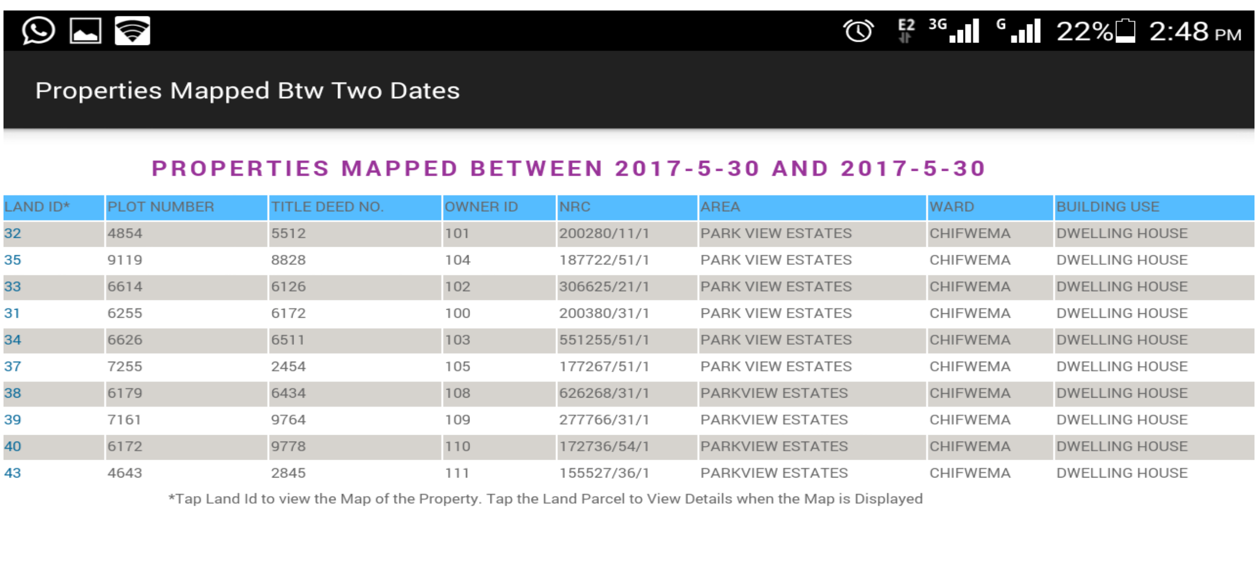


Fig. 7. Mapping using device GPS.



Properties Mapped Btw Two Dates

PROPERTIES MAPPED BETWEEN 2017-5-30 AND 2017-5-30

LAND ID*	PLOT NUMBER	TITLE DEED NO.	OWNER ID	NRC	AREA	WARD	BUILDING USE
32	4854	5512	101	200280/11/1	PARK VIEW ESTATES	CHIFWEMA	DWELLING HOUSE
35	9119	8828	104	187722/51/1	PARK VIEW ESTATES	CHIFWEMA	DWELLING HOUSE
33	6614	6126	102	306625/21/1	PARK VIEW ESTATES	CHIFWEMA	DWELLING HOUSE
31	6255	6172	100	200380/31/1	PARK VIEW ESTATES	CHIFWEMA	DWELLING HOUSE
34	6626	6511	103	551255/51/1	PARK VIEW ESTATES	CHIFWEMA	DWELLING HOUSE
37	7255	2454	105	177267/51/1	PARK VIEW ESTATES	CHIFWEMA	DWELLING HOUSE
38	6179	6434	108	626268/31/1	PARKVIEW ESTATES	CHIFWEMA	DWELLING HOUSE
39	7161	9764	109	277766/31/1	PARKVIEW ESTATES	CHIFWEMA	DWELLING HOUSE
40	6172	9778	110	172736/54/1	PARKVIEW ESTATES	CHIFWEMA	DWELLING HOUSE
43	4643	2845	111	155527/36/1	PARKVIEW ESTATES	CHIFWEMA	DWELLING HOUSE

*Tap Land Id to view the Map of the Property. Tap the Land Parcel to View Details when the Map is Displayed

Fig. 8. Viewing mapped properties report.

Fig. 9. Viewing mapped land parcels.

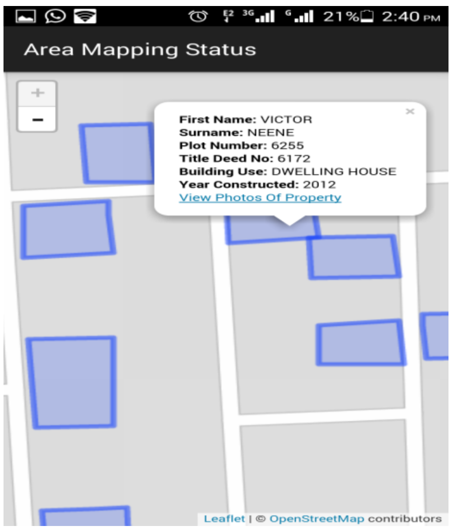


Fig. 10. Tapping mapped land parcels.

Fig. 11. Viewing property images.

VI. Application Modelling

This section presents the results of the final application modeling that was achieved after the several requirements formulation iterations.

A. Entity Relationship Diagram(ERD)

Fig. 12 shows the ERD of the application. The development of the ERD first started by identifying the entities from the business rules. There after the relationships between the entities were identified and the multiplicities and participation were also identified appropriately. There after primary and foreign keys for each entity were also identified. This was followed by the identification of other attributes for each entity. Lastly, the ERD was reviewed and revised by following the steps described until the final ERD was developed. The entities that were identified were the location, map, user, land, valuation, property, owner and individual. The ERD depicts the primary keys, foreign keys and attributes.

B. Class Diagram

Fig. 13 shows the classes that were developed to model the Application. The classes modeled the map, location, land, owner, property, valuation and individual entities in the property mapping problem. The relationships among the classes and methods of the classes are also shown. The map class can have one or many instances of the location class. It can also have one or many instances of the land class. The land class can have one or many instances of the property class. It can also have one instance of the location class. The property class can only have one instance of the valuation class. The owner class can have one or many instances of the property class. It can also have one or many instances of the location class. The individual class inherits from the owner class and re-implements the public functions.

C. Mapping System Sequence Diagram

Fig. 14 shows the System Sequence Diagrams (SSD) of the mapping spatial and image data. It depicts the exchange of messages between the mapper and the system. The user sends a message to the system to open the property mapping screen and the system responds by opening the screen. The user then sends a message with an owner id to the system and the system responds with the property details. A create map message is sent together with the captured GPS coordinates and the system responds with a confirmation message after successfully creating the map. The user then sends a save image message with an image and the system responds with a confirmation message after saving the image successfully.

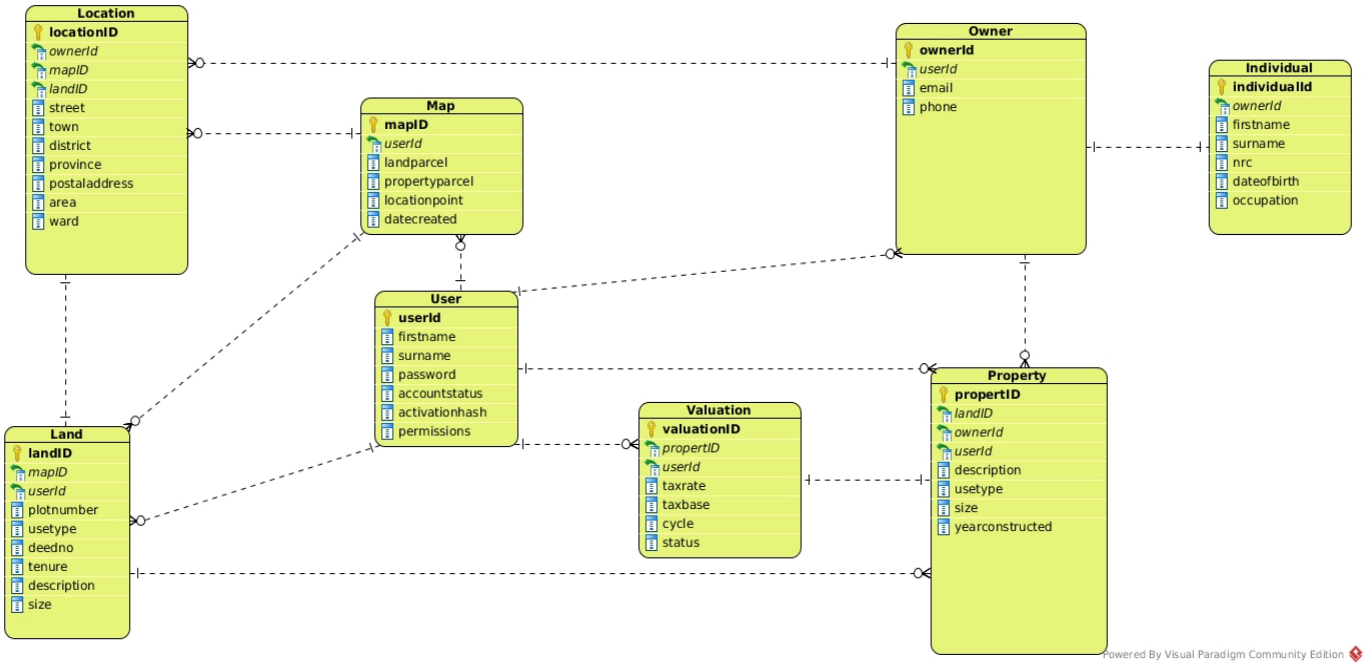


Fig. 12. ERD for the property mobile mapping application.

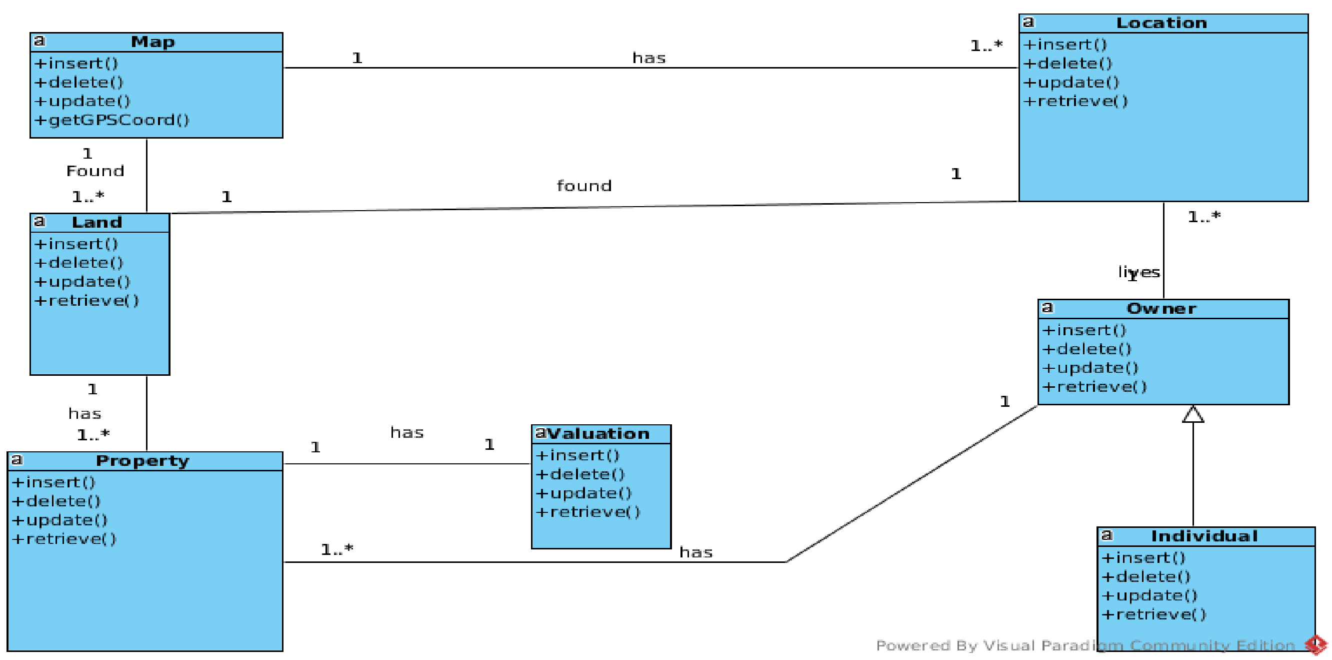


Fig. 13. Class diagram for the property mobile mapping application.

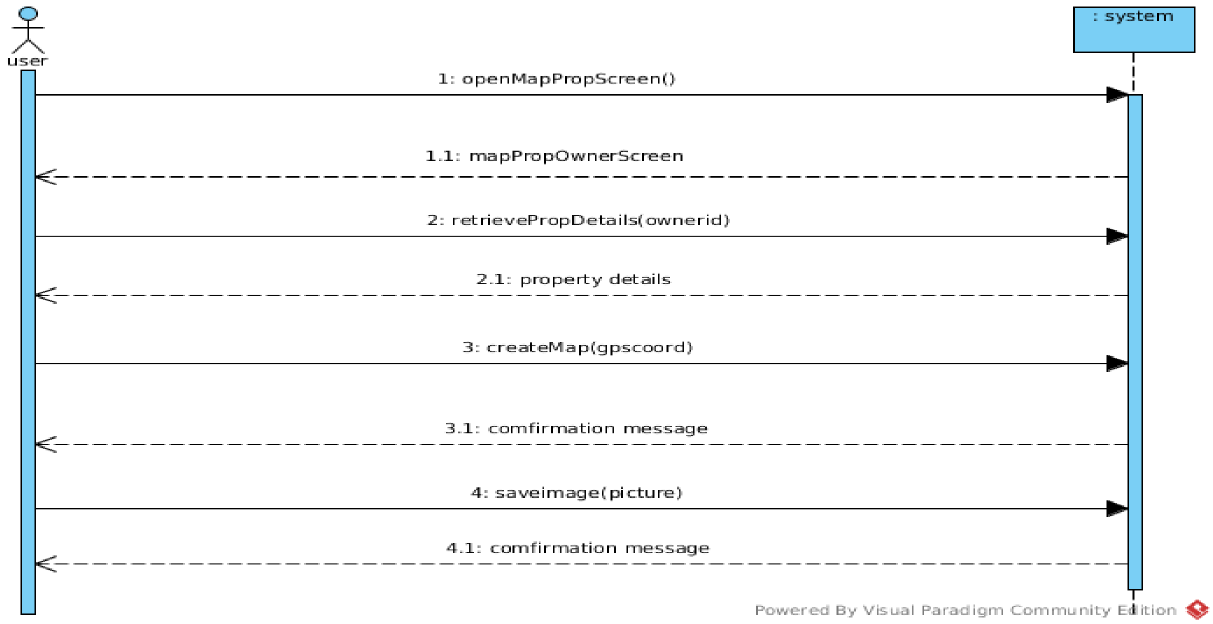


Fig. 14. System sequence diagram for the mapping spatial and image data mapping.

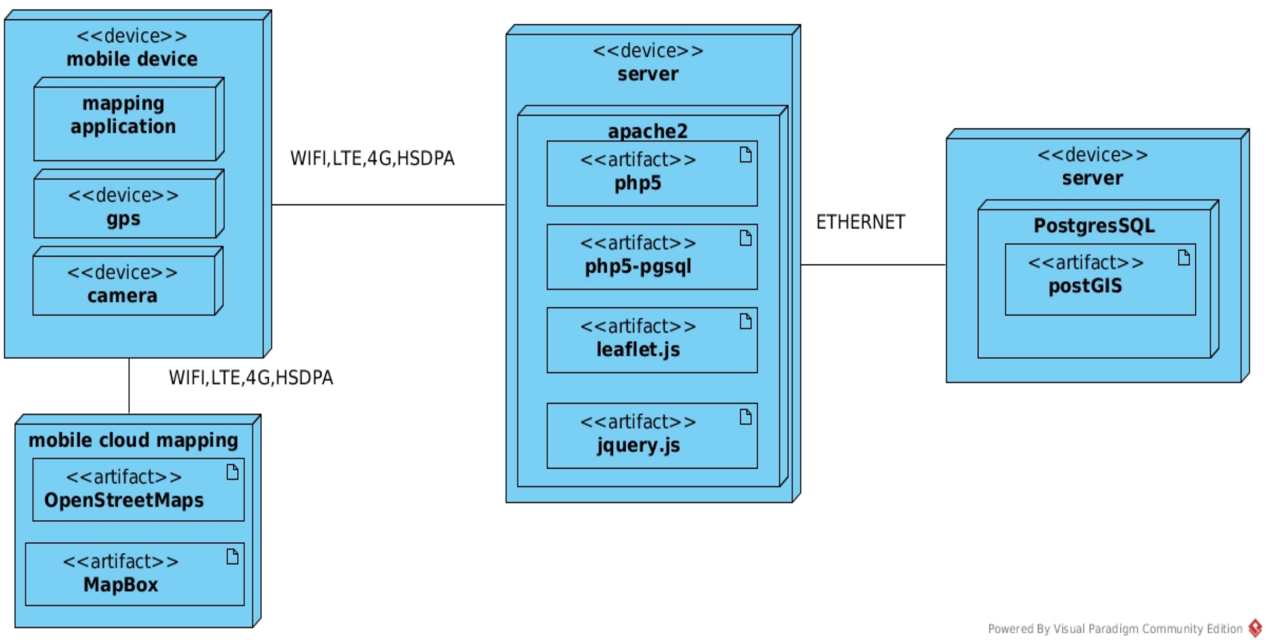


Fig. 15. Deployment diagram of the mobile application.

VII. System Architectural Design

Pressman describes System Architecture as the manner in which the various parts of the software system are integrated to form a cohesive whole. The components can include a simple program module, object oriented classes, databases, middle ware, networks, clients and server hardware. System Architecture is important because it enables communication among stakeholders involved in the computer based system development. It also simplifies the model of how the system will be structured and how the components will work together [21]. Fig. 15 depicts the Deployment Diagram of the mobile application. The following sections describe the components depicted:

A. *Mapping Application Component*

The mapping application component constitutes the frontend that runs natively on the mobile device. It uses the mobile device's GPS and camera hardware. It is interfaced with the Apache2 web server and the mobile cloud mapping services.

B. Mobile Cloud Mapping Component

This component is invoked by the Leaflet library mapping code that is loaded from the apache2 webserver. The leaflet library in turn renders the OpenStreetMap vector and the MapBox raster maps provided by the mobile cloud computing services. The library also provides a map drawing tool plugin for capturing the property GPS Coordinates from the vector and raster maps.

C. Apache2 Webserver Component

The webserver component hosts the php business layer logic, JavaScript leaflet library and the jquery image display code that interfaces the mobile application (front end) and the PostgresSQL database (backend). The php5-pgsql API connects to the spatial database server. The php, leaflet and jquery code are invoked by the mapping application component during user interface interactions.

D. PostgresSQL Spatial Database Server Component

The database server component is made up PostgresSQL with PostGIS extensions Spatial relational database and it performs the role of the backend. The database is accessed by the php scripts residing on the Apache2 webserver component through the PostgresSQL php5-pgsql API. The API performs database manipulation and retrieval operations.

E. Network Connectivity

Network connectivity is provided by WIFI, LTE, 4G, HSDPA and Ethernet technologies to move data among the components.

VIII. Comparison of the Mobile GIS Property Mapping Application with Related Applications

Our Mobile GIS property mapping application and the related applications described in the literature review section all have a component of capturing GPS coordinates either through a GPS Device or Geo-referencing a digitized map. However, some key differences pertaining to implementation exist.

The related applications require the digitization of maps of the area where properties are located. The maps are obtained either from primary or secondary sources. The process of digitization requires the use of desktop GIS productivity software. In contrast, our mobile GIS application uses existing digitized vector and raster maps of the property area provided by OpenStreetMaps and MapBox cloud computing mapping services respectively. Secondly, related applications capture data using a two stage approach. Spatial data is first captured in the office and then attribute and image data is later captured in the field. Thereafter, all the three data sets are then integrated as one. Our mobile GIS application, on the other hand, captures all the three data sets holistically in real-time in the field and in one session. Thirdly, related applications use Microsoft Access database, Microsoft SQL database or databases that are embedded in the GIS desktop productivity applications. In contrast, our mobile GIS application uses PostgresSQL with PostGIS extensions relational database that is designed specifically to store and process primitive geographic data types. Fourthly, related applications do not use the Leaflet mapping library that enables mobile mapping on mobile devices as compared to our mobile GIS application. Lastly, related applications do not use existing wireless technologies in their implementations; hence, they are devoid of mobility and full multiuser capabilities. In contrast, our mobile GIS application is fully mobile and multiuser.

IX. Discussion

The results of the mapping demonstrated that the application can be an efficient and useful tool in mapping of properties in the real time setting. The real time aspect has the advantage of capturing complete property data on the spot as residents will be available to provide the attribute data pertaining to their respective properties. Secondly, a good number of properties can also be captured over short periods of time and that would result in the clearance of property capture backlogs. Thirdly, on the local authority part, they can also hire and use non GIS experts in the mapping exercises because of the intuitive characteristics of the mobile mapping application user interface. Lastly, on the technological front, mobile computing, cloud computing and opensource software tools used in the development of the mobile GIS mapping applications have shown that it is possible to develop robust, user friendly and efficient mobile solutions. The cost of building mobile applications when these technologies and tools are used will be low because they can be used and obtained freely or at a very minimal cost.

X. Conclusions

In this study, the development of the mobile GIS property mapping application was presented. Affordable opensource development software tools and mobile cloud computing mapping services were used in the development and implementation of the mobile mapping application. A review of GIS based property mapping applications that were developed was conducted. The review showed that these applications lacked real time capture of complete property data and they used GIS desktop productivity software that required the skills of highly trained GIS experts. The study has shown that mobile GIS mapping applications can be developed by using mobile cloud computing services and opensource software tools. The mobile mapping application can help local authorities, especially in developing countries, in overcoming the challenges that they experience in property mapping.

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The Informative Vector Selection in Active Learning using Divisive Analysis

Zareen Sharf
Assistant Professor
Shaheed Zulfiqar Ali Bhutto Institute of Science & Technology

Maryam Razzak
International Islamic University
Islamabad

***Abstract*—Traditional supervised machine learning techniques require training on large volumes of data to acquire efficiency and accuracy. As opposed to traditional systems Active Learning *systems* minimizes the size of training data significantly because the selection of the data is done based on a strong mathematical model. This helps in achieving the same accuracy levels of the results as baseline techniques but with a considerably small training dataset. In this paper, the active learning approach has been implemented with a modification into the traditional system of active learning with version space algorithm. The version space concept is replaced with the divisive analysis (DIANA) algorithm and the core idea is to pre-cluster the instances before distributing them into training and testing data. The results obtained by our system have justified our reasoning that pre-clustering instead of the traditional version space algorithm can bring a good impact on the accuracy of the overall system's classification. Two types of data have been tested, the binary class and multi-class. The proposed system worked well on the multi-class but in case of binary, the version space algorithm results were more accurate.**

Keywords*—*Active learning; machine learning; pre-clustering; semi-supervised learning

I. Introduction

Machine learning plays a vital role in the concepts and models that are related to artificial intelligence. It can be simply defined as a procedure, which makes the computers so intelligent that they can assist the human in some of the most difficult and time-consuming tasks, like decision-making, forecasting, pattern recognition etc. The most distinguishing feature of machine learning is that it empowers the machine to learn how to behave and react in a certain situation based on the rules and patterns it drew from the training dataset.

We are living in a world exploding with information. Data is everywhere in the form of, tweets on social networks, comments/reviews on popular blogs, threads on networks, daily publications and news feeds to name only a few sources. The need of the hour is to make our information systems so intelligent that they can extract, transform and reproduce this huge volume of data into a form useful for analysis and prediction. For example, consider a disease discovery system. A disease has certain sets of symptoms and after effects. This information can get updated if we are able to continuously extract new and unique information from the data which is being stored and updated in the patient's history.

The classification of text is the process of assigning a set of predefined categories to the document on the basis of content present in the document by Yang & Liu [16]. Classification could be on the basis of labeled data. The volume of which may vary according to the method used. One of the shortcomings of labeled data is that it is not readily available. The process of labeling data is an expensive task as it involves a lot of human effort. This problem brought new areas of research and most popular of them are Semi-Supervised Learning and Active Learning. They both aim at solving the problem of labeling unlabeled data by using a significantly small volume of labeled data [18].

Active Learning is a technique of semi-supervised machine learning which enables the learning algorithm to query a user interactively and be able to infer desired outputs for newly admitted data.

Active Learning can be implied on many domains where we have large amount of unlabeled data present and labeling tends to be a hard issue in terms of cost, time, and human effort; for example, in drug discovery [14], natural language processing [10], information extraction [9], information retrieval [15] and many more.

II. A Review of Semi Supervise Learning

Semi supervise learning is the basis of most of the active learning techniques. Semi-supervised learning and active learning both tackle the problem of dealing with unlabeled data with only a small volume of labeled data [19].

Many studies have been undertaken for the purpose of comparison between supervise learning and semi-supervise learning like Zhu & Wu [18] proposed a technique for handling noisy datasets. The researchers mainly focused on improving cost sensitive classification. They started by applying a general classification strategy that integrated the misclassification of cost for noise handling. Then they boosted up their research by bringing a semi-supervise classification type strategy in which the noise detection results were added to the training iteration by iteration and the accuracy of overall system in noise identification was improved. The major focus in their work was given to the cost of expensive classes, which was actually giving all the focus to some of the classes while the others were being neglected. This could cause inaccuracy in the calculation of the predicted value of the most important class; therefore, causing all the results to become unpredictable.

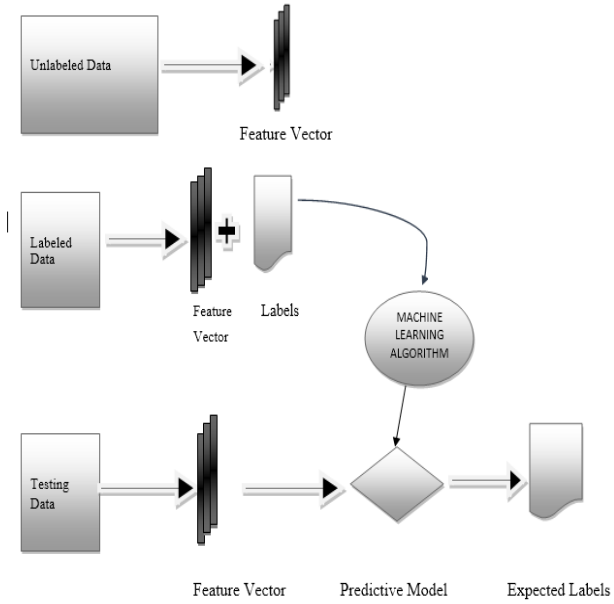

Fig. 1. A semi-supervise learning model.

The Semi-Supervise learning process can be well explained with a diagram. Fig. 1 depicts a structure of semi-supervise learning. On the top we have the unlabelled data having just one attribute and that is the feature vector which contains details of the features of the data other than class. A portion of the unlabelled data is selectively chosen and labeled by a human expert. This labeled data goes to the machine learning algorithm enabling it to learn a mathematical model from it. Next the remaining portion of unlabeled data is fed to that algorithm in the form of testing data. The algorithm then predicts the expected labels of the data according to its prediction model.

Semi supervised learning has received a lot of attention in the field of clinical research. Automated text analysis specifically in electronic health records (EHR) using natural language processing and machine learning have become very popular in the recent decade [13]. The paper proposed an automated system for selecting clinical records that could contain valuable information regarding disease diagnosis or regarding the symptoms of some disease. The classifier was trained on the records of numerous patients diagnosed with a disease. The major advantage of the proposed system was that it did not require any human effort. The proposed model could achieve good efficiency as it was trained based on careful selection of the training data.

III. Literature Review

The term active learning gained popularity among researchers in the 1980s [1] and since then it is a very rich area of research. The main idea proposed by Angluin [1] was that the learner may have the option to ask queries that might be related to its membership (For example, is this instance member of A class or not.), relevance (For example, is this instance related to this class or not?) etc. The learner alters the value of instances by asking queries and thus after a specified number of iterations a model can be generated.

Machine learning gains efficiency using active learning as it reduces the human effort required for labeling the vectors/instances. It gives the system liberty to choose the vectors/instances that will be labeled. This is achieved by defining a selection criterion for the vector, which would be labeled and then used as training set for the classifier. In this way, the input domain of the classifier can be defined efficiently.

Active Learning can be classified into two modes, single and batch mode. Therefore, the first step is selection of mode. Next is the selection of a suitable active learning technique. Two of the active learning techniques popularly used are: Pool Based Active Learning and Stream Based Active Learning. Pool based active learning as the name suggests, works for a large pool of unlabeled data while the stream based active learning works dynamically for a live stream of unlabeled data. Our proposed model will work on a large pool of unlabeled data. Finally, we are left with the selection of approach/strategy for active learning by which the sample of training data will be selected. The most common active learning strategies are 'error reduction strategy for sample selection', 'uncertainty based strategies for sample selection', 'uncertainty sampling with Bias', 'uncertainty sampling with prediction' and 'relevance based strategies for sample selection'. The strategy that we have followed in our work is the uncertainty based sample selection.

Biswas & Parikh [2] has proposed an active learning system following an attribute based feedback process in which the learner not only queries for the labels of the instances but the human expert also gives his feedback about the query. This established an interactive connection between human and machine and this project was further applied for image classification. The human expert played the role of a supervisor to teach visual concepts to a machine. For example, for a certain image, the learner says, "This is a garden, what do you say?" the supervisor might respond saying, "No, this is too open to be a garden". After getting the feedback of the supervisor, they also introduced a weighing schema for checking the likelihood of any image; thus, enhancing the active learning process.

Active Learning supports multiple instance learning [17] and this process is being commonly adopted because research is now shifting from working on a single instance to a bag of multiple instances. Moving on to the bag instead of single instance can be risky in terms of computational cost. To overcome this problem Yuan & Liu [17] proposed a model of pairwise similarity based instance reduction for Multiple Instance Learning (MIP). The process was dependent on the similarity among the instances within a bag, which was named as training bag. Better performance could be achieved if pair of instances without using the concept of bags was used.

Hu et al. [4] used a simple active learning process for selecting the most informative query that was created with the help of support vector machine. The overall process worked in the binary class domain and initially it started with two instances in the hyper plane, one positive and the other negative. As the process continued, the values of hyper plane kept changing and the instances were selected according to their minimal distance from the hyper plane. The overall system's accuracy was above 90 percent and a major contribution of the new system was that, it was not working on an artificial dataset as the dataset was being assigned a proper location near or far from the hyper plane.

Our proposed model is very similar to this work and to summarize the entire process we begin with a large pool of unlabeled data and follow a batch mode of active learning technique by which we selected a certain number of vectors as training data and applied pool based active learning on it. Finally, the uncertainty based sample selection procedure was used on the tested vectors that our classifier labeled according to its model.

SVM is one of the most popular and frequently used classification Models. According to a statistical learning theory it is the best classification technique for binary classification. Apart from performing just binary classification, this classifier if merged with some other active learning approaches could give better results in multi-class systems as well.

IV. Issues Regarding Designing of Active Learning Algorithm

The process of Active Learning starts with some preliminary decisions that are required for a successful implementation of an AL system. The tools and algorithm used for the active learning procedure will be discussed in the later section. First point of concern is to deal with some issues that are common for all learning algorithms.

The first issue is related to defining some selection criteria for choosing unlabeled data. Mostly, it is done randomly because at start, we just predict a small sample to be informative and then after applying our technique we dig out where the good ones are located. This work can also be done by Pre-clustering, which requires some solid boundaries for picking the informative vectors.

Second issue is to decide the size of the initial training set. The size of the training set is very important, as the performance of the classifier depends on how well it is trained. If we take a small subset of data from a particular dimension, then our classifier will be bounded in its decisions. This problem does not arise in incremental Learning as the training set incrementally gets appended by new and informative examples. For selective learning, this issue requires attention because based on initial training set the classifier will recognize the patterns/features and will perform the later tasks.

Third issue is to define the stopping criterion. The stopping criteria can be pre-defined and post-defined. In most cases, we see that stopping criterion is developed when observations have been made on the initial selection of data. A very general stopping criterion of this type is the one which checks for the performance of trained classifier after each iteration and then it stops the overall system when the classifiers performance ceases to improve.

Fourth issue is the selection of classification algorithm. Active learning mostly doesn't have any particular classifier that is used for AL only and in most cases, it uses the typical classifiers that are used for machine learning. There are many classifiers available for supervising learning tasks but the selection of a problem specific classifier is very critical. For example, if we have to do active learning for document classification then we will have to explore which classifiers perform well in that domain.

V. Active Learning Scenarios

According to the fore mentioned concept of supervised learning, a random set of training data was always being selected for the classification but it was actually stopping the performance of overall system at some point. To overcome this issue, the term active learning was developed which actually gave the freedom of selecting the most informative training data for some valid requirements. Two most general scenarios of active learning that are used in majority of the active learning systems are: Pool Based Active Learning and Stream Based Active Learning.

A. *Stream based Selective Sampling*

The stream based selective sampling is utilized when we do not have static data and the learner has to process a continuous stream of data.

From Fig. 2, it can be seen that the learner, which is any algorithm is getting a dynamic stream of unlabeled data. At first it gives the data directly to the human expert for labelling but once it gets trained on a model then it decides by itself whether to give it to human expert or discard it being unimportant.

The work done by Kapoor & Horvitz [5] is based on discarding, caching and then recalling the samples in active learning. They have performed the classification in stream based environment. The main idea of the paper was based on the observation that dynamic data like handwriting recognition data may vary over time so instead of discarding data after labeling we must have some recall function that may ask for the label of same data after some iteration. Their stream based setting was repeatedly based on decisions of removing data from active stream, then caching those decisions and then recalling that data later in future. It was found that the proposed setup was very beneficial for learning especially when we have to update our model for the new coming data.

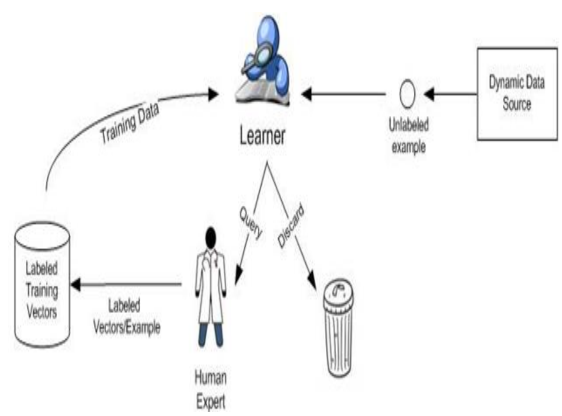

Fig. 2. Stream based active learning model.

Stream based sampling often faces the challenge of deciding whether to label a given instance or not. A possible solution to this issue could be the informativeness of the instance, which happens to be our central research idea. This could be done through selective sampling algorithm a discussion on these algorithms will be done the following section.

Another very interesting observation in the domain of stream based selective sampling was that some researchers were using this to enhance the pool based active learning. Moskovitch & Nissim [8] have done selective sampling in order to enhance their **SVM** classifier, which was working mainly on the pool of unlabeled data. An online detection system for the unknown computer worms was developed and the data was taken by monitoring 323 computer features which were later reduced to 20 after feature selection. The stream based sampling was actually utilized to get the real-time records and the performance was observed to be considerably improved after the addition of active learning with the simple **SVM** classification.

The term active learning has been utilized in the context of **exploration** and **exploitation** by Loy & Hospedales [6]. They developed a system that worked opposite to the previously used heuristics method in Bayesian classification. According to them if the process of classifying the image and videos was extensively used it could produce better results. A learner would be fed ambiguous instances constantly while a human expert would keep on labeling. Both activities would take place simultaneously. This process continues until the entire posterior distribution of classes have been utilized. During this process a committee of previous hypothesis was made. Thus, two hypotheses were created for each instance. If the classifier showed disagreement on both hypothesis, then that instance would be directed to the human expert for labeling. Next the instance that got labeled by human annotator would be sent to the classifier as training data. This model outperformed all the previous stream based active learning systems but a limitation in the system was that, it did not handle noisy data well. Thus, in case of any noise in the data the hypothesis might get affected and cause the overall system's accuracy to deteriorate. The system can be further enhanced by tackling the noise in online streams of data.

By the time, the advancement in areas of research is bringing new concepts into the domain of active learning. The area of concept drifting was introduced under the stream based active learning range. As we know that the data in streams carries the requirement of getting predictions in real time and here the main issue that can arise is concept drifting. So the learning should be so strong and adaptive that instances don't get wasted from memory without getting labeled. In the paper by Zliobait & Bifet [20] three active learning strategies had been adopted to overcome the above-mentioned problem. The three concepts are based on uncertainty, randomization and dynamic allocation of data. The results proved that the proposed strategies of splitting data according to concept drift performed very well especially when the labeling resources are very small.

B. *Pool based Active Learning*

Real time data is available in huge volumes. The task of labeling this data belonging to various domains gave rise to the concept of Pool Based Active Learning. Usually queries are drawn from the pool which is non-static in their nature, but this is not always the case as there can be presence of dynamic data at some instances. The major difference between stream based and pool based active learning is that the first one sequentially goes through all the data while the latter deals with multiple instances at a time in the form of a huge pool of data.

Pool based active learning has been performed in many real-world scenarios, like Text classification, image classification, disease diagnosis, speech recognition etc. Much of the work in active learning is done by the technique of pool based, Maccallum & Migham [7] have utilized it for reducing the cost of labeling for a huge set of unlabeled data. The model of (Query by Committee) QBC was extended with the key aim of getting the density of the document explicitly at the time of selecting the examples for labeling. They proposed a probabilistic framework that was based on the EM algorithm in addition to the typical active learning framework. The combination of density weighing methods and EM with active learning methods proved that the accuracy of the system could be improved by having a small training dataset. A limitation to this system was the density estimation which is difficult to calculate especially when dealing with high dimensional data. The work could be further improved by combining the concept of poor probability with the density weight scheme. The techniques for interleaving EM and active learning could also be explored to improve performance.

Ganti & Gray [3] used pool based active learning to overcome the problem of binary classification. The proposed system was named as UPAL (Unbiased Pool-based Active Learning) which tries to minimize the unbiased estimator of risk. The proposed system was developed assuming there was no noise in the data and it only worked towards unbiased sampling of the labeled data. This made the model quite rigid as such requirements were hardly ever satisfied by real time data.

Pool based active learning can be carried out for a single instance selection mode or multiple instance selection mode. Wang & Kwong [11] performed the Pool Based Active Learning for Multiple Instance selection criteria. The work was performed on MNIST handwritten data and almost 100 bags were created from the whole pool of unlabeled data. The Multi-criteria decision-making procedures were applied for the selection of bags with the help of active ranking. It was seen that the bag margin based active learning outperformed the random sampling as well as the simple SVM active Learning procedures.

VI. Instance/ Vector Selection

Once the active learning technique, whether Pool Based or Stream Based Active Learning, is selected the next stage is selection of the most informative instances. For the Selection of instances, many strategies have been applied in active learning some of which are 'Error reduction/estimation based strategies', 'uncertainty Based strategies', 'Uncertainty sampling with prediction', 'Uncertainty sampling with bias', 'Inconsistency based uncertainty sampling', 'Relevance based selection strategies' etc.

In our work, we have focused on uncertainty based sample selection strategies. According to the concept of Query by Committee (QBC) algorithm, a committee of classifiers is developed and trained on different training data. Then a Test data is provided to all classifiers for the sake of predicting class labels. After that the labels of all classifiers are compared and the instances which carry highest value of uncertainty are selected for first querying the human expert and then being added into the training data of main active learning classifier.

The selection strategy of an active learner mostly revolves around two concepts: one is Query Construction and the other is Selective Sampling

A. *Query Construction*

In query construction an arbitrary value is given to a query which is then forwarded to the expert for labeling. The arbitrary value chosen is mostly the extreme possibility of any situation and is well suited for the purpose of training the learner system. For example, if we are required to classify a document we will either add the exact keyword (required to keep the document as a member of certain class) in the arbitrary query or we will give it extreme negative keywords that might be slightly related to the keyword of that class. Query construction is not applicable in most of the classification problems as it is based on the system's/ expert's knowledge rather than being based on patterns found in the data.

B. *Selective Sampling*

A relatively more practical approach than query construction is the selection sampling. This approach proceeds by selecting the query from the large pool of unlabeled data. In in this approach the learners' select queries from the dataset provided and then forward it to the expert for labeling. Thus, labeling is done on real time data rather than arbitrary data making the training process more authentic.

This research also focused on the selective sampling technique and but before that we applied a pre-clustering technique. Pre- Clustering technique divides the data into as many clusters as possible and then the query is selected by taking one, two or more members from each cluster. Pre-clustering assists the active learner to get trained on data coming from each data distribution therefore, various types of data get labelled and classified making the learning process very robust.

Before going into the details of the proposed system, we will discuss the base work by Wang & Kwong [12] which has been implemented in the experiments of this research. Wang & Kwong [12] followed the same procedure for finding the inconsistency based active learning but they worked on the version space concept of general to specific ordering. The GS ordering is always performed on binary class data. We on the other hand have tried to extend this model to work with multi-class data.

The version space algorithm processes a given pool of data based on two hypotheses. According to hypothesis one: it labeled all the data instances as positive while the second hypothesis labeled all the data instances as negative. Two separate SVMs were trained on the dataset from both of these hypotheses and then the testing of those SVMs was performed on the same data. According to concept of QBC both the classifiers give their classification results for testing data. The conflicting data was collected in separate metric and an inconsistency value was added as a feature to all that data. For training, the member with higher inconsistency value was selected for being labeled by the human expert. Finally, the labelled instances were provided to the final classifier as training data.

The modifications made to the base work has been discussed in the next section.

VII. Proposed Architecture

The Active Learning task is always initiated with a random training data which later gets updated with each iteration. The initial data was selected so as to represent data from all the areas of the pool and for that purpose equal volume of data had been provided from each of the cluster that were generated by the DIANA algorithm. A working model of DIANA is shown in Fig. 3.

The Learning of the classifiers continues until it has added a pre-defined number of training vectors after which the process of learning terminates. The testing was done iteratively by assigning different sizes of training data L. Since the data gets selected randomly on each iteration that's why the results generated were different from each other on each run. We checked for the consistency of the results and they were found to be quite consistent for most of the instances.

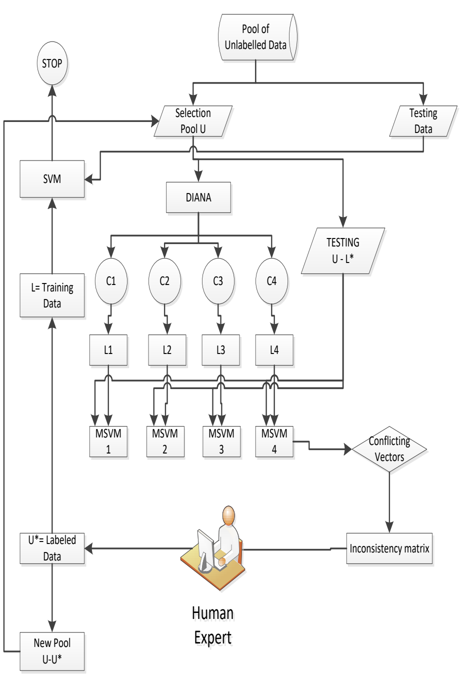

Fig. 3. System architecture for active learning with divisive analysis.

Since we started with the idea of keep our training dataset as small as possible we initially restricted the value of L to be 90. However, since the number of vectors in binary data are usually high therefore the value of L was raised to become 120.

The first and foremost task of this proposed architecture is the handling of noisy data. We have applied the procedure of Mean Average for tackling the missing values in the data. This allowed us to fill in all the missing values with the mean value of the remaining parameters.

To validate the performance of our proposed system, we did a comparison of our classifier with existing real time labeled data and after that the accuracy of the system was calculated.

VIII. Divisive Analysis (DIANA)

We selected a hierarchical clustering algorithm for our model. In simple clustering data is divided into a number of groups that are based on the similarity between objects but in hierarchical clustering a proper hierarchy of objects is built. The unique feature of our work is the pre-clustering in which the divisive analysis-s algorithm is used. In this algorithm we create a hierarchy of clusters. Traditionally used clustering is not applied here because we want to get as many clusters as the level of resolution among the data allows us. Another reason for not using simple clustering methodology is that the initial number of cluster are unknown at the start of the process. This problem can be rectified by hierarchical clustering which gives us the freedom of choosing N number of steps to produce a suitable number of clusters for our analysis.

The DIANA algorithm is applied here to check for inter cluster similarity among two are more chief clusters. In DIANA the hierarchy is created in the inverse order, we start from the most general form in which we have two clusters and then from those clusters we move on to as many clusters as possible. DIANA initially starts with one cluster which contains all the data instances. On every iteration the larger clusters split up into two clusters and this process continues until every object belongs to its own cluster. The whole hierarchy in DIANA is built up in N-1 steps.

The Overall algorithm of DIANA proceeds as follows.

1) Get the objects having highest level of dissimilarity with all other objects and this becomes the splinter group.

2) For every object ‘i' compute the following formula:

$$D_i = [average \quad d(i,j)\, j \notin R_{splintergroup}] - [average \quad d(i,j)\, j \in R_{splintergroup}]$$

3) Let’s suppose we have an object h for which we have to calculate the distance D_h using the above-mentioned formula. If the value of D_h is largest and also if it is positive, then we can say that h is close to the splinter group but on an average.

4) The 2nd step is repeated until we get all the values of D_h to be negative. At this point the whole pool will get divided into two groups.

5) The cluster having the largest diameter will get selected as the largest dissimilarity between any of the two objects. Next, this cluster will get further divided.

6) All the above steps will keep on being repeated until we get one object in each cluster.

IX. Multilevel Classification via Support Vector Machine

Support Vector Machine commonly known as simply SVM is basically a binary classifier but it can be turned into a multiclass classifier by combining some of its’ approaches. Following is a discussion on some of the variants of SVM:

A. Multi-SVM

The main classifier of SVM was developed in 1995 by Cortes and Vapnik and since then it has proven to be one of the best classifiers for binary classification of data. The main concept behind SVM is to plot the whole data on a high dimension space and try to bring a maximum margin hyperplane among the sets of data.

Some of the common approaches for the multi-SVM are:

- One Against one
- One against All
- DAGSVM

In this study, we have followed the one against all approach which is described in the next section.

B. One against All

SVM was primarily designed for binary classification problem but then it was extended to work with multiple classes. One Against All is an extension of SVM in which we construct *k* SVM models that deal with *k* number of classes. Suppose we have an i^{th} SVM which is trained on i^{th} class that has all instances of positive labels and all other examples with negative labels. Now if we are provided with the training data, l, which is in the form $(x_1, y_1).........(x_i, y_i)$

Where, $x_i \in R^n,\ i = 1.......l$ and $y_i \in \{1,......,k\}$, which is actually the class of x_i. The i^{th} SVM will now solve the following problem.

$$\min_{w^i, b^i, \xi^i} \quad \frac{1}{2}(w^i)^T w^i + C\sum_{j=1}^{l} \xi_j^i$$

$$(w^i)^T \phi(x_j) + b^i \geq 1 - \xi_j^i, if \quad y_j = i$$

$$(w^i)^T \phi(x_j) + b^i \leq -1 + \xi_j^i, if \quad y_j \neq i$$

$$\xi_j^i \geq 0,\ j = 1,.....,l$$

Where, C is the penalty parameter in the above mentioned equations and the function ϕ is actually mapping the data x_i

on the higher dimensional space. In the above equation the main part is minimizing the

$$\frac{1}{2}(w^i)^T w^i$$

which actually shows that we should maximize the $2/\|w^i\|$ margin between the two groups of data. The main aim behind the SVM classification was to search for a balance between the regularization term

$$\frac{1}{2}(w^i)^T w^i \quad .$$

And the errors obtained while training the data.

After finishing with the above mentioned problem the k decision functions were checked.

$$(w^1)^T \phi(x) + b^1 \quad .$$

$$(w^k)^T \phi(x) + b^k$$

Now we can say that z is the class, which has the largest number of decision functions:

$$class\ of\ z \equiv \arg\max_{i=1,\ldots,k}((w^i)^T \phi(z) + b^i)$$

X. Experimental Setup

For the demonstration of the results achieved by the proposed method, two datasets have been used. The comparison has been made with the study conducted by Wang & Kwong [12] who applied inconsistency based active learning with the help of version space's general to specific ordering. The Key objective of this work is actually the comparison of version space with divisive analysis (DIANA Algorithm). Some of the features of our proposed system are the handling of missing values with the help of average mean formula and the comparison of final classifier's results with the actual values of the data and then calculating the overall accuracy. The datasets were taken from the UCI machine repository and the details of both datasets are represented in Tables 1 and 2.

TABLE I. User Knowledge Modeling Dataset

Dataset Details	
No. of attributes	5 Plus class
No. of instances /vectors	259
Attribute Characteristics	Integer
Missing Values	No
Variables to be predicted	Knowledge level of use (very low, low, middle, high)

TABLE II. Pima Indian Diabetes Dataset

Dataset Details	
Total Attributes	8 Plus class
Missing values	Yes
Instances/Vectors	768
Attribute types	Numeric
Variables to be detected	Presence /Absence of Disease

XI. Training and Testing Data

Gendat function is used to generate data randomly for testing and training; according to that 70 per cent data is used randomly for training and 30 per cent for testing. Random selection of the instances follows the prior probability of the class. So the estimation of the sample that would be selected from the particular class is equal to P*N, where P is the prior probability of the class. And N, is the percentage of the data for training.

XII. Results

The Classification work is performed under MATLAB R2010a and the 'SVMtrain' and 'SVMPredict' functions have been used from LibSVM. The Algorithm has been executed on a computer with 2.13GHz Intel Core i3 processor with 2 GB memory and Windows 7, 64-bit Operating System.

As we have worked for the betterment of accuracy and decrease in the computational cost so the results have been shown in terms of time consumed on each iteration and then the accuracies attained in each iteration with different volumes of 'L' which is the training data.

The results have been obtained from the classifier in different iterations, as on each iteration, the classifier chooses random available data and thus the accuracy may vary. Although random results are generated after each run but accuracy still remains better than the base method. This leads us to believe that the base system (Active Learning with Version Space) is not iterative in nature as the classifier always gives the same accuracy and performance regardless of the length of execution. Fig. 4 shows a graph for all the values of L for which we have tested both systems.

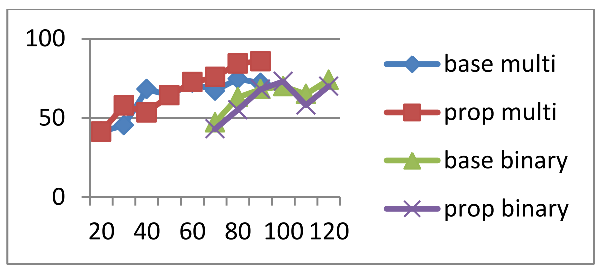

Fig. 4. Accuracies of both systems with binary and multi-class data.

XIII. Overall Classification Accuracies of Both Systems on Multiclass Data

From the results shown in Table 3 and Fig. 5, we can observe that the rate of accuracy is increasing with the increasing values of 'L'. It is also noticeable that the proposed classifier's accuracy is better than the base method's classifier.

TABLE III. Accuracies in Terms of Percentages of Both Systems with Different Values of L on Multi-Class Data

Method	**L=20**	**L=30**	**L=40**	**L=50**	**L=60**	**L=70**	**L=80**	**L=90**
AL with version space	41.25	45.33	68.06	64.29	72.06	67.16	74.60	72
AL with Divisive Analysis	41.25	57.87	53.37	64.25	72.5	75.75	84.25	85.69

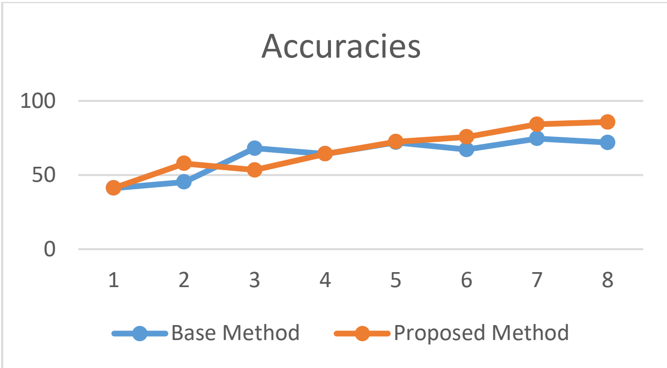

Fig. 5. Accuracies of both system on multiclass data.

Another significant observation is that for L=20 the accuracies of both the systems were same and the obtained accuracies after following 10 iterations also came out to be same. This may be because of the value of L=20 instances out of 258 instances proved to be an extremely small sample size and so the actual performance gain of the proposed algorithm could not be accurately measured. This is the reason both algorithms have run to a level that is similar to the normal classification and because of this the results of each iteration obtained from both of the algorithms stays the same.

XIV. Comparative Analysis of Baseline and Proposed Classifiers on Binary Data

In the previous section, we discussed the performance of our classifier with respect to a user knowledge database which happened to be multiclass database. In this section, we will discuss the results obtained for Pima Indian Diabetes database which is a binary class database. From the results depicted in Table 4 and Fig. 6, a clear comparison of our technique can be seen for both the binary data and the multiclass data.

TABLE IV. Accuracies in Terms of Percentages of Both Systems with Different Values of L on Binary Data

	L=70	L=80	L=90	L=100	L=110	L=120
AL with version space	46.03	55.55	56.37	61.90	69.84	72.22
AL with Divisive Analysis	44.26	49.20	53.17	62.69	65.87	67.46

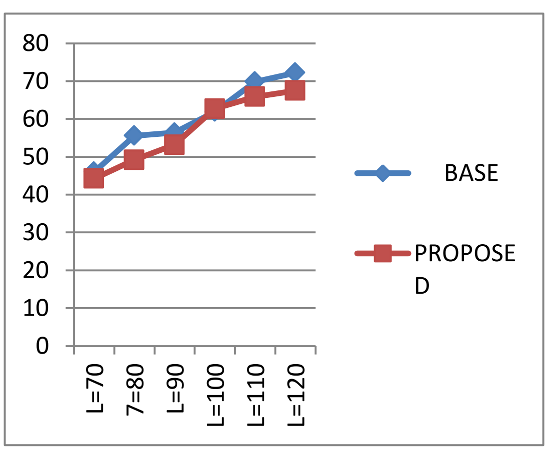

Fig. 6. Accuracies of both system on binarydata.

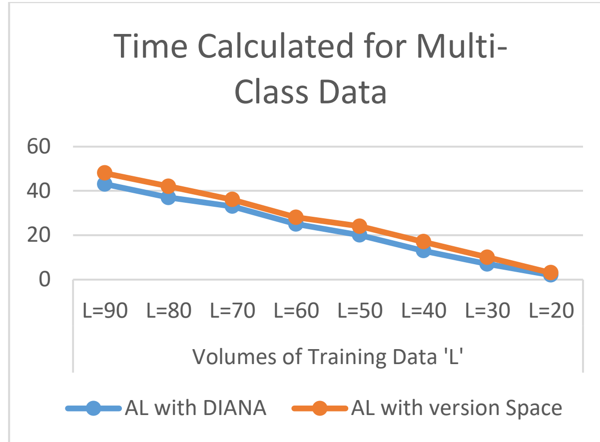

Fig. 7. Calculated time for both systems in multi-class enviornment.

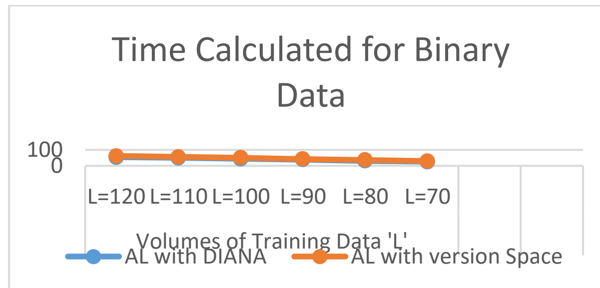

Fig. 8. Calculated time for both systems in binary enviornment.

The results obtained on the binary data are not up to the mark as in most of the cases the proposed method is lagging behind the base method. The dataset here consisted of 768 vectors and the sample amount of training data that we have chosen to represent the results of our technique, ranges between 70 and 120. It can be clearly viewed that in most of the cases the accuracy of proposed method is below the accuracy of the base method when working with binary data.

Apart from the accuracies another major challenge of this work was the computational cost in terms of time. It has been noticed that although the proposed system with DIANA clustering has not attained a good consistency in the accuracy for the binary data, but as shown in Fig. 7 and 8, on both types of data, the calculated time of the proposed system was better than the base system and this was even more consistent as compared to the accuracies.

XV. Conclusion

From the experimental setup, it has been observed that the proposed technique which is basically the implementation of pre-clustering approach in active learning brings an observable change in the performance of the overall classification of the system. The main idea behind any active learning system is to reduce the computation cost & time. The proposed idea is an effort to improve the performance of the baseline classifier. We begin with the assumption that, if the classifier gets trained on a logical group of data rather than one based on random assumption then its accuracy can be improved. This hypothesis was further validated to be correct for the multi-class data.

On the other hand, the proposed model did not produce any performance gain for the binary data. It was observed that the version space algorithm works better on binary data. A disadvantage of version space algorithm as stated by Zhu [19] is that it does not work well in cases where there is noise found in the data and also in the case when the learning concept tends to be disjunctive in nature. The major contribution of this research is the comparison of version space with multiclass clustering and as stated above the results have shown that the multiclass clustering performs better in case of data with multiple classes but in the case of binary data the version space algorithm performed better.

The aim behind the usage of version space or DIANA is to minimize the cost of classification system and in our work. We pre-clustered the data according to divisive analysis clustering (DIANA) procedure and then train the classifier on a fixed ratio of vectors from each cluster. This approach brings a training data that carries member from each group of the given pool of data and thus the classifier trained on this diverse data shows better performance than the classifier that gets trained on a supposed group of data. The volume of training data was also reduced considerably.

XVI. Future Work

The traditional concept of active learning follows the selection of instances and asks the user to label those instances but with the same technique and with the same proposed method one can extend this work for the feature selection. The feature selection phenomenon can be used individually for any research and it can also get summed up with the instance selection as well.

We have worked on the pool based active learning scenario but the work can be extended in almost the same way for the stream based active learning scenario which works for the dynamically coming data streams.

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Smart Tourism Architectural Model

(Kingdom of Saudi Arabia: A Case Study)

Ahmad H. Al-Omari
Computer Science Division, Faculty of Science
Northern Border University
Arar, Saudi Arabia

AbdulSamad Al-Marghirani
Faculty of Higher Studies
Northern Border University
Arar, Saudi Arabia

***Abstract*—The researchers have proposed and implemented a general application architecture model that complies with the demands of the Saudi tourism sector to be used by tourists on their mobile devices. The design architecture aims to improve tourism sector opportunities, facilitate tourists' guidance in the holy and historical places, fill in the shortage of having multilingual tourists' guides, cut off cost expenses and build up capacities. It can support KSA to be a tourist attraction in the region. The research project employs the usage of the Quick Response (QR) codes and the Information Communication Technology (ICT) which are capable of converting the smart phones into a tourist guide device. This new system can be considered as a Smart Cicerone (S-Cicerone). The research project has a flexible design that allows tourists, guests and administrators to interact easily with the system in order to use its services and perform a regular system update and management. The system design is based on component-based architecture including Tourist Layer services, Smart Tourism System Layer services and the Administration Layer services. The components are divided into further services and smartly integrated to formulate the main application functions. This project is meant to be implemented in the Kingdom of Saudi Arabia as a pilot project and is also valid for implantation in any other countries.**

Keywords—Smart tourism; smart systems; QR-Code; Saudi tourism; Saudi Vision 2030; S-Cicerone

I. INTRODUCTION

Smart systems facilitate daily life activities by using sophisticated appliances which integrate and function seamlessly with minimal human intervention [1]. Smart systems may employ the touching technology "Smart Touch Technology STT" for functionality. However, smart systems are defined to be the integration of technologies and services through networking for a better quality of living standards [2]. The term Smart has been added to different applications to indicate smartness in such systems. For instance, smart cities imply the use of smart system technologies to achieve resource optimization, effective and fair governance, sustainability and quality of life. Smart tourism, smart home, smart factory, smart traffic, smart card, smart TV and so on are examples of employing the term smartness in the real world for the beneficiary of the end user [3].

Smart tourism is a modern expression that implies the use of emerging forms of Information and Communications Technologies ICT with the tourism industry and which allows the exchange of massive data for better tourism services [4]. The term Smart describes economic and social developments armed with technology that utilizes sensors, hardware, software, embedded systems, big data and special connectivity (i.e. Internet of Things (IoT), Radio Frequency Identification (RFID), Quick Response (QR) code, and Near Field Communication (NFC)).

The Kingdom of Saudi Arabia "KSA" has launched its future vision "Saudi Vision 2030" which covers many sectors including tourism. In the tourism sector, the vision states that "we will enrich pilgrims' spiritual journeys and cultural experiences widely in KSA. We will establish more museums, prepare new tourist and historical sites and cultural venues, and improve the pilgrimage experience within the Kingdom." [5]. By 2025, the tourism industry is expected to create over 930,000 jobs [6] which means that tourism in KSA is very promising and needs more capital and technology investments which are mainly the high concern of the public and private sectors. The Saudi Commission for Tourism and National Heritage published its road map for the Saudi tourism for the years 2002-2020. The commission stated that currently the Saudi tourism sector relies on the cheap labor of people from South East Asia to cover the tourism sector jobs. The commission has launched a training program "Ya Hala" to train 1.5 million Saudi people in the tourism sector. This rehabilitation program includes many tracks such as the tourism guide, learning languages and many other tracks.

II. TECHNOLOGY IN TOURISM

A. Facts and Tools

Tourism is considered as one of the largest industries worldwide. It generates about 11% of the global gross domestic product (GDP), employing more than 200 million employees worldwide, and serving more 700 million tourists each year [7]. Recently, the adoption of ICT has changed the traditional viewpoint of tourism from conventional towards electronic tourism (e-tourism). Using smartphones-based services to provide smart tourism might be called smart tourism instead of e-tourism. Different technologies have been adopted to support using technology in tourism. For instance, Internet of Things (IoT), Radio Frequency Identification (RFID), Quick Response (QR) code, Near Field Communication (NFC) are examples of such technologies. In this work, the researchers have chosen the QR-code for implementation.

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B. Quick Response (QR) Code Technology

A Quick Response (QR) code is a type of barcode that can save information about certain object. The amount of information is much more than the traditional bar codes. This technology is accessible for any smartphone equipped with a camera, a QR code reader/decoder and a network connection. The QR codes are widely used in video streaming, online menus, advertising campaigns, linking to websites, and signing up to pages [8]. QR Codes have a well-constructed error correction scheme that allows recovery of damaged codes up to 30% of the damage [9]. The QR code orientation is usually managed and adjusted automatically by the QR code reader [10]. The only limitation on reading the code is the reading distance.

Some facts should be already known about the QR codes. It is worth mentioning that these facts call for either mandatory or optional requirements. Some researchers mentioned the basic facts and QR code requirements as listed below [11]:

1) A QR Code is 2D Barcode.

2) QR code can store a variety of data (Typically: 7,089 numeric characters without spaces or 2,953 alphanumeric characters with spaces and punctuation).

3) Most smartphones can scan QR codes for Reading/Decoding purposes.

4) QR code can be placed in nearly any location.

5) There are some other types of QR codes (Data-Matrix code, Google tags, PDF417 and AZTEC) [12].

6) To run a QR code you need the following:

a) QR code generator (website service)

b) QR code reader (mobile application)

c) Optional QR code management/tracking tool (website service)

d) Generators: Different generators have varying features. Choosing a generator is based on the options for:

i. Code Format (i.e. QR, EZcode, Tag, etc.)
ii. Stored Data (i.e. hyperlink, meCard, SMS, etc.)
iii. Output (i.e. color, size, download file type, etc.)

7) Management tools are available to track scanning analytics.

8) QR code content should provide special value for the customer.

9) Small or complex QR codes can’t be scanned by smartphones with lesser quality cameras.

10) Testing scan ability factors are:

a) Smartphone cameras (resolution/auto-focus)

b) Reader apps

c) Scanning context (i.e. lighting, shadows, surfaces)

d) Scanning distance

e) Scanning timing

f) Scanning angle

g) Scanning in different environment conditions.

III. Related Works

Some governments in Europe like Australia and Asia (i.e. China and South Korea) have started to support smart tourism infrastructure. The governments’ interests differ from region to region but all of them care about end-user applications that enrich tourism experiences [3].

Different tourism institutions from different countries over the world have conducted research work and implemented tourism applications in different forms. In the research [7] Smart Travel Guide: Application for Android Mobile, the researchers have proposed using android-based application to provide timely information for tourists and tourism institutions whenever it is needed. Mash-up technologies along with web-based applications have been used to collect and manipulate the requested information like the weather and the tourist’s current geographical location, map, and distance between cities. The Smart Travel Guide has the choice to retrieve the required information either as text, picture or video formats.

In the work of [3], the researcher introduced an overview of the smart tourism concept. Koo identified smart destinations, smart business ecosystems and smart experiences as the three basic components supported by layers of data creation, processing and exchange. He also defined using technology in tourism as an infrastructure rather than individual information system and focused on the traveler as the user of the system. The system aims to support travelers by three services. First, it suggests user’s needs and interests like dining and accommodation. Second, it enhances travelers’ experience by offering information, location-based services, maps, inquiries and interactive services. Third, it shares travelers’ experiences. The research work has distinguished between e-tourism and smart tourism, not only in the technologies it employs but also in the approaches that make use of tourist experience and feedback.

In the work presented by [13], they discussed the problems that face the tourists in their travels. The collaborative nature of tourists is used to design implications on how we could build better tourist technology. Tourists usually work together in groups, negotiate and arrange their activities according to their schedule. The system allows tourists to collaborate, share and exchange their experiences and activities. It also aims to help tourists gain experience and plan their visits beforehand by means of shared practices such as maps that show the current ‘social structure’ of the city. The system has expanded and become part of the City project; it has developed tourist best activities to support cooperation between local and remote museum visitors and has explored media in city life.

Juho Pesonen and Eric Horster [14] expected the NFC to be one of the tremendous technological progress in the coming few years especially in the travel and tourism sectors. They also presented the several NFC implementations and possibilities. NFC offers tourism many useful tools and applications. Juho and Eric reviewed earlier researches in NFC technology and investigated the current state of NFC technology usage in tourism companies. They considered the several critical issues that affect the commercial success of the NFC mobile service. These issues are stated as the slow adoption of NFC mobile-based services, unclear revenue that are attractive to end users and the fact that there is no business model to handle diverse interests and possible conflicts. A generalized approach for NFC application development is being developed which is the inclusion of the Mobile Network Operators and Service Provider in this model. Smart posters as advertisements is another usage of the NFC where the user can hover the phone over the NFC tag located on the poster and have a URL transferred to the smartphone. Then the user can easily follow the link. Benyó, on the other hand, presented NFC-based application that is capable of handling a smart shopping cart system for retail stores. This system eliminates the need to stand in line in order to pay. Another implementation is the indoor navigation system that is called NFC Internal. Spreading the NFC tags over a building enables easy data to transfer for indoor navigation just by touching the tags. Utilizing social media is another possibility of using NFC applications. For example, Hot in the City is an NFC application that allows users to make friends by touching other users' NFC devices through the peer-to-peer mode. [15]

IV. Proposed Solution

The Smart Tourism System (STS) is a funded research project that attempts to support the Saudi vision 2030 on the context of improving the tourism sector opportunities. STS aims to help the Saudi tourism authorities to facilitate marketing and managing the tourists' activities in the holy ancient and historical places while keeping tourists' privacy safe. The project also aims to fill in the shortage of having multilingual tourists' guides, cut off cost expenses, build capacities and hence prepare KSA to be a tourist attraction in the region. It thrusts the country to switch up from the traditional models of monolingual to multilingual approach.

The STS research project employs the usage of the QR codes technologies to facilitate access to the information of the historical and ancient places in KSA. Once the QR code is scanned, the project will:

1) Convert the smartphone to operate as a smart well-trained multilingual tour guide with a professional guiding experience.

2) Show pictures of the place along with its history.

3) Display a proposed guided tour walk through the site.

4) Operate on behalf of the tourism help desk in the sense that it can demonstrate how to start and end the tour timely and manageably.

5) Maintain tourist privacy and give the tourist the opportunity to move freely anywhere and anytime without being confined with the tourist schedule.

The following sub sections explain the proposed solution in more details.

A. STS Assumptions

The researchers assume the following:

1) Tourists are aware of the existence of the Smart Tourism System STS application in the site location.

2) Tourists have already uploaded the STS application from Google/Apple store.

3) Tourists' smartphone is ready for mobile data and/or Wi-Fi connection.

4) Tourists' data plan and credit allow access to the STS services (The ministry of tourism might provide Wi-Fi access, either free or paid, that covers the whole site).

5) Tourists are aware of using and utilizing QR codes.

6) The QR codes are easy accessible, cannot be tampered with and clearly shown to tourists.

7) The QR codes are large enough to be scanned from distance. The relationship between scan distance and minimum QR code size is approximately 10:1. So a 2.5^{cm} QR code requires an effective scan distance of about 25^{cm}, and a 50^{cm} QR code size requires an effective scan distance of about 5^{meters} [16].

B. STS Constraints

The research constraints are out-of the control of the project and can limit the design alternatives. The following summarize some of these constraints [17]:

1) Mobile data connection speed might not support the required audio/video streaming speed.

2) The research project will only cover Arar ancient mosque, as the first phase (pilot project). After that the researchers will cover some other historical ancient sites before launching the final project countrywide.

3) The NFC tag phase will be implemented on the second phase of the project.

4) Implementing the project might face resistance from some tourists' guides since the project might threaten their careers.

5) Using Google maps will be limited to the allowed Google terms and conditions of free access (i.e. 2500 free request per day). In case of requested charge fees for any Google map service, that service will not be supported.

C. STS Component Services

Fig. 1 shows the main system components services including Tourist Layer services, STS Layer services and the Administration Layer services. These layers are integrated together to generate the main system services. The three layers services are logically divided and categorized according to the type of the offered service.

The Tourist layer services are intended to provide tourists with registration and authentication and allow tourists to share their experience and provide feedback. However, the STS layer services generate location-based and content delivery services. The type of content delivery depends on the type of the user whether he/she is a registered or a guest user [18]. The Administration layer service mainly concerns about the administration control services and the database management and tuning services.

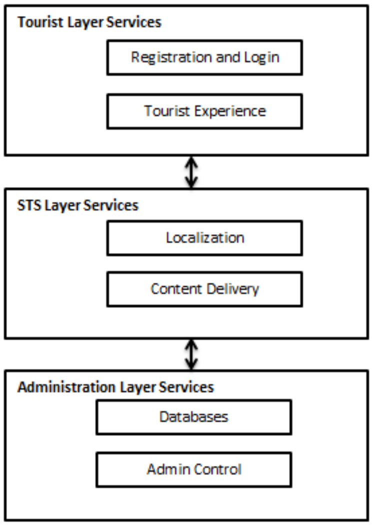

Fig. 1. STS component services.

The separation between the three different layers is a logical separation rather than a physical one and it is for control purposes only. This separation makes the STS services more manageable.

D. STS Workflow

This section presents the working flow of the mobile tourist guide system. Firstly, we assume that tourists have already registered with the system and provided their personal information. Afterwards the system services can be categorized as shown in Service architecture[19]:

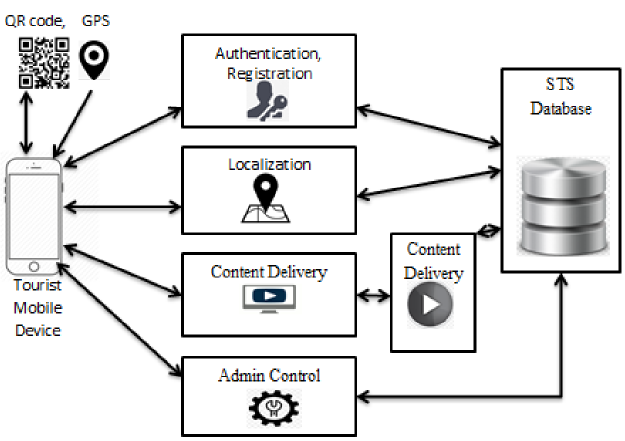

Fig. 2. Service architecture.

The algorithm shows the basic STS services. These services can be listed in the following steps:

1) Initialization step: It prepares the STS application to operate; it turns on the available internet connection (i.e. Wi-Fi or mobile data) and the QR code reader, GPS services and the STS application.

2) Registration step: It aims to encourage tourists to register their basic information in the STS database. In this sense, the registration process builds a communication channel between tourists and the tourism agencies to enrich the tourist experience and add more future customer services depending on tourists' notes and feedback. The services offered to the registered tourist are not restricted; they can enjoy the full STS system services like listening to audio, watching video, reading textual data and providing feedback. In case of those users who are not registered, the system will ask the user to register.

3) Check the tourist type step: The STS have three types of users: Guest user, Registered user, and Admin user.

The users' functions and services are:

1) The Guest user is allowed to access only the limited STS services so that to encourage different tourist to register, share their experience and provide feedback about their tour in order to enhance the STS services based on the tourist feedback.

2) The Registered user can use the full STS system services and provide feedback.

3) The Administrator user can control the system, add, modify, delete STS data, generate reports, calculate statistics and perform system maintenance. In short, the administrator can monitor the system performance and control the access to the system. The STS can provide the administrator with different types of reporting like number of played videos, the peak time of playing videos, most frequent videos usages and so on.

4) Reset credentials: Registered tourists can reset their passwords and change their basic personal information.

E. STS Architecture

System architecture is composed of different system components to support the system functionality. The grouping components methodology is very common when building mobile applications. The application designer usually takes into consideration grouping the components into areas of concerns and focuses based on interaction between the different components and how those components work together [20].

Fig. 3 shows the architecture and design. The STS application is a piece of code that is designed to be installed on the tourist mobile phone. It contains the main tourist services like scanning the QR/NFC tags, choosing the language preference, defining location, mapping the nearest place to visit and providing tourist feedback. The Localization contains the location and tagging services. The location service is connected to the Global Positioning System GPS which provides the users' current and nearby locations. Moreover, the Wi-Fi/Mobile data connectivity is provided here to facilitate the Internet access. The Tagging services are the QR-code or NFC tag that are posted on a specific location and they contain the link address to access the required information either by watching the video streaming or getting the textual information about the desired location [21]. The Processing Center service is responsible for answering the users' queries and providing the required information in a specific format (i.e. video streaming or textual information) and it allows tourists to provide feedback about their experience.

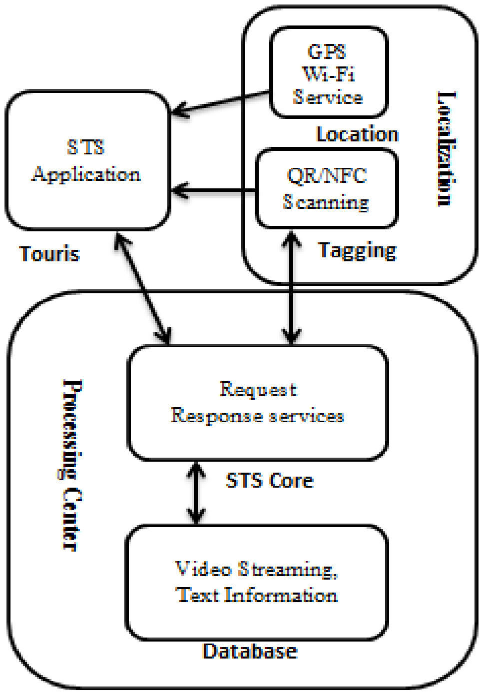

Fig. 3. Architecture and design.

F. Algorithm Description

The STS is designed to operate on Android devices on the first phase. Then it will be expanded to cover other operating systems in later phases of the project, i.e. iOS and Windows Mobile [19].

First of all, the tourist is supposed to install the STS application from the digital distribution platforms for mobile devices (i.e. Google play). The tourist device is supposed to be connected to a Wi-Fi/ Mobile data connection, and for better services, it is recommended to turn-on the GPS services. Once the tourist has installed the STS application, the STS services should be available upon request. The tourist can access the services either as a registered tourist or as a guest. When accessing the services as a registered tourist more services can be offered by the system.

The following algorithm summarizes the general STS services as follows:

Start
Initialize / Internet, GPS and mobile data connection initialization*
/ Camera, QR-Code reader and application initialization*
If new tourist / check for the type of user*
If like to register
Register for service / Not registered user and wants to register*
*Get username /*Assign login ID for future authentication*
Assign password / Set new credentials*
Else
*Login as Guest /*not registered user and want to login as Guest*
End-if
Else
Provide login credentials / Already registered user*
If Valid credentials / provide the user ID and password (Authentication)*
Determine user type (Tourist, Admin)
Else
Enter valid credential / want to reset password or forget password*
Reset credentials
Loop
End-if
End-if
Case user
*Guest user /*Guest Services will be provided*
Get basic services
Get tourist guide in text format / only textual data is provided*
No available feedback services
No available GPS services
Valid authentic Tourist / Full STS services will be provided to a registered user*
Get STS services
Get tourist guide in audio, video and text format
Get feedback services
Get available GPS services
Valid authentic Admin / Administrator services will be provided*
Get STS services
Update STS raw data in different format
Get STS reporting and statistics
Perform system maintenance and tuning
Monitor system performance and tourists' feedback
End-case
End

V. Comparison with Other Systems

None of the related work mentioned above provides the same service as the STS does. For most of the above mentioned works either focus on tourist services like booking accommodation, flights, restaurants and entertainment or help tourists explore or navigate attraction. On the other hand, the STS project aims to convert the smartphone device into a handy smart tourist guide with no extra charges. Table 1 shows a brief comparison of STS with other similar works.

TABLE I. STS COMPARISON WITH OTHER SYSTEMS

Service/ usage or support	STS Smart Tourism System	Smart Tourism via Smart Phone	Travel Guide: Application for Android Mobile
IoT support	Yes	Partially	No
QR-Code usage	Yes	Partially	No
Smartphone based	Yes	Yes	Yes
Web-based support	Yes	Yes	No
Entertainment	No	Yes	Yes
Tours guides	Yes	Yes	Yes
Booking and Reservations	No	Yes	No
Rating and Feedback	Yes	Yes	No
Multi-lingual tourist guides	Yes	No	No
Cloud Computing	No	Yes	No
Location Based Services	Yes	Yes	Yes
Weather Forecast	No	No	Yes
Calculate Distance between Places	Yes	Yes	Yes

VI. CONCLUSION AND FUTURE WORK

The STS system can be a multilingual and a well-trained tour guide system with a professional guiding experience and which is considered as a replacement of a human tourist guide. The STS can show pictures and display a proposed guided tour walk through the site. It can also be a beneficial tool for the tourism help desk in the sense that it can organize the tour smoothly. However, it can also keep the tourists' privacy safe and help the tourist move freely without being confined with the tourist guide schedule.

In the future, many smart services can be added to the system like smart object sensing and recognition, service rating, tourist crowded estimation, hotel booking, ticket buying, restaurant reservation, car renting and many other services. The STS could be implemented in the holy and historical places in the Kingdom of Saudi Arabia as a pilot project and is valid for implantation in any other country.

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Role of Expert Systems in Identification and Overcoming of Dengue Fever

Dr. Nadeem Ahmed
Department of Computer Science
Superior University
Lahore, Pakistan

Adeed Ishaq
Department of Computer Science & IT
The University of Lahore
Lahore, Pakistan

Muhammad Shoaib
Department of Computer Science
Sharif College of Engineering and Technology
Lahore, Pakistan

Abdul Wahab
Department of Computer Science
Superior University
Lahore, Pakistan

***Abstract*—This paper presents a systematic literature review on expert systems which are used for identification and overcoming of Dengue fever. Dengue is a viral disease produced by Flavivirus. The expansion of Dengue fever is because of uncontrolled population and urbanization without suitable water administration. With the quick technological enhancement, we can identify and overcome Dengue fever by using expert systems. These expert systems require knowledge of the relevant problem and techniques to infer the result in order to make decisions. The literature review provides a comparison of techniques, methodologies, limitations and advantages of different Dengue expert systems. These expert systems facilitate both doctors and patients in Dengue detection. Multiple risk factors can be eliminated by the detection of Dengue fever through expert systems at early stages of Dengue. Furthermore, we find that enhancement of knowledge base improves accuracy of expert systems.**

Keywords—Expert system; rule based; Dengue; health care; disease; fever

I. Introduction

Dengue fever is one of the viral diseases around the world that is caused by blood feeding mosquito. Dengue fever happens due to a single stranded RNA Flavivirus, which is transmitted by mosquito bite [1], [2]. It is one of the most emerging diseases of the world [3]. There are about 20-80 million cases annually and majority of these are diagnosed as flu that causes about 24,000 deaths every year. Due to lack of proper treatment around 2.5% of the infection results to be fatal. The symptoms of this fever include joint pain, headache, muscle-pain and skin rashes [4]. Dengue ranks as the most important mosquito-borne viral disease in the world [5]. Countries which are most effected by Dengue are more than 110 in number [6]. Mainly this is due to bad sanitary conditions in underdeveloped countries. The experts provided a number of solutions regarding Dengue diagnosis but due to inexperienced doctors it is still misclassified [7]. Thus, throughout the world the experts are facing the problem of diagnosis of Dengue due to its misclassifications. The diagnosis process is quite time consuming which make things more complex. Much time is required for the identification of its correct classification. There is no problem in diagnosis if the number of patients is less but if they are huge in numbers and the country has limited resources then it becomes problematic to correctly diagnose this fever. The Dengue fever issue motivates computer experts to devise an automated and time efficient solution that correctly classify the Dengue. These automated systems for Dengue diagnosis can be deployed in faraway places as well as in epidemic situations to save precious lives.

In computer science those systems that can solve a specific problem and can reason rationally are known as Expert Systems. Expert systems require knowledge of the regarding problem and techniques to infer the result in order to make decision [39].

Today there exists a number of expert systems for disease diagnosis as for bacterial infection MYCIN, for lung disease PUFF, for angiograms ANGY, for edema PIP, for meningitis diagnosis NEOMYCIN, for chest pain MED1, for bacterial infection GUIDON and for hematological disease HEME [8]-[10]. There are several types of expert systems based on knowledge base, i.e. rules, cases, hybrid approach (rules and cases) and hybrid approach with ANN like Medical Expert Solution (MES) system [25]. The MES uses a knowledge base which consists of two knowledge structures, named as symptom and diseases. The MES provides medical facilities to those users who don't have access for it. Further, we will discourse research methodology, different mosquito borne diseases, related work, discussion, conclusion and future work.

II. Research Methodology

A. Rsearch Question

RQ1: Does expert systems correctly identify Dengue fever?

RQ2: Does knowledge base of expert system fulfill the requirements?

RQ3: Does interfaces of expert systems are user friendly for all type of users?

B. Search Strategy

After observing and viewing all aspects of expert systems a research has been carried out on expert systems for Dengue. The field of computer science plays a major role in this perspective because it provides us the tools and techniques for gathering data from massive data stores/sources.

1) Identification of Search Terms: From research question extract major terms and check their synonyms for search related research papers. These terms verified in relevant papers. OR operator use for concatenation of synonyms words. AND operator use for concatenation of major terms.

2) Trial search: Trial search conducted by using the following search string in Science Direct, IEEEXplore, SpringerLink and ACM digital library. Table 1 contains complete information of digital libraries with search items and search conduction date.

("Dengue" OR "Fever" OR "Malaria" OR "Rule based" OR "Artificial Neural Network") AND ("Identification" OR "Overcoming" OR "Expert system" OR "Task" OR "Factors" OR "Challenges" AND OR risks OR problems OR "issues")

TABLE I. TRAIL SEARCH RESULTS

S. No.	Digital library	Search	Conduction Date
1	IEEE Explore	144	01 January 2017
2	ACM Digital Library	118	10 January 2017
3	Google Scholar	101	15 January 2017
4	Science Direct	12	20 January 2017
5	Site Seer Digital Library	11	25 January 2017
6	Springer link	8	29 January 2017

C. Study Selection Criteria

Some of the papers are relevant to our research and properly defining our research scope. These papers have been included here that helped in the research and those papers which are not relevant to our research, not properly defining our research scope and their language is different, are excluded.

1) Inclusive Criteria: After viewing different papers some papers are, giving the answer of our research questions, defining our search terms, their language is English and within our scope, these papers are included.

2) Exclusion Criteria: Some papers are not within a scope or not written in the English language which is prescribed in this paper, or not giving proper answers of our research questions, such type of papers is excluded.

D. Data Extraction and Assessment of Study Quality

As our inclusive criteria is defined, we have gathered the data which is relevant to our research, fulfilling our requirements and defining the scope of our research, also it will guide us for quality study.

E. Electronic Data Stores

We search related data from the following electronic data sources:

- www.ieeexplore.ieee.org
- www.acm.org
- www.sciencedirect.com
- www.citeseer.ist.psu.edu
- www.scholar.google.com
- www.springerlink.com

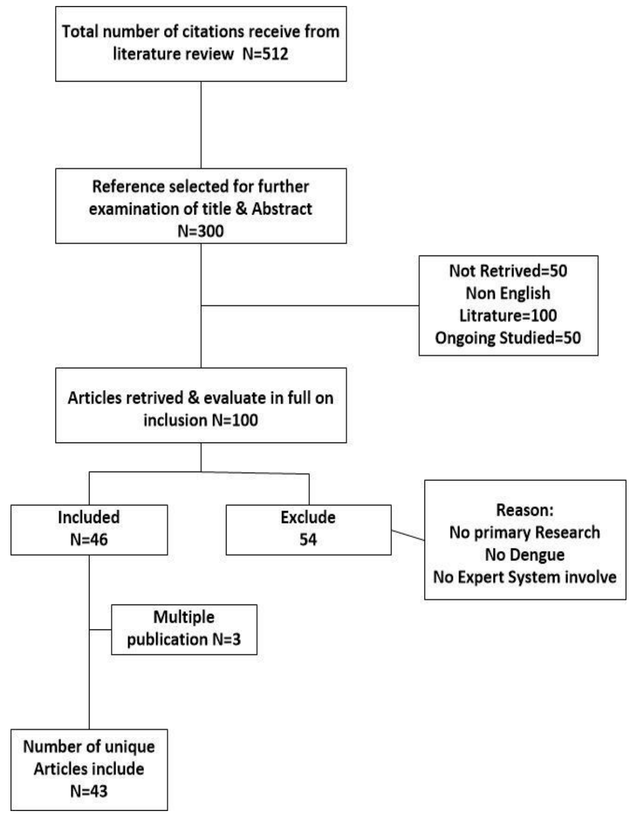

Fig. 1. Research methodology.

Fig. 1 shows complete research process and number of research paper included in our study. Duplicate publication and non-primary research studies exclude.

III. DIFFERENT MOSQUITO BORNE DISEASES

Here we describe the origin of different mosquito born disease. These diseases have some common symptoms with others. Some are viral while other are non-viral. Viral diseases are either due to mosquitos like Yellow fever, Malaria, Dengue and influenza [11], whereas non-viral are natural diseases such as heart diseases, diabetes and cancer. Unlike non-viral diseases, the viral diseases can spread in short spans of time and are difficult to handle. Fig. 2 expresses hierarchical structure of viral and non-viral diseases.

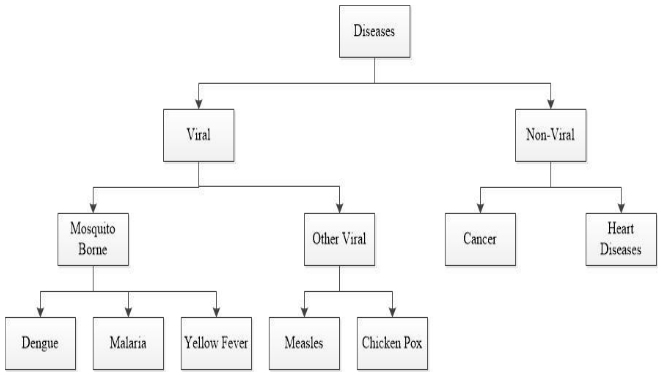

Fig. 2. Viral and non-viral diseases.

A. *Diseases Due to Mosquitos*

These diseases are caused by viruses that are transmitted by mosquitos. Which includes Dengue, Yellow Fever and Malaria [12]. In past years' research shows that there is leap in diseases caused by mosquitos. This motivates researchers and scientists to work to reduce these diseases [13]. Fig. 3 presents complete detail of mosquitos borne diseases.

1) Yellow Fever: It is one of the infectious diseases which is caused by Aedes mosquito that is infected by Flavivirus. This mosquito is usually found in sub-tropical or tropical regions [14].

*Signs and Sympto*ms: Yellow Fever happens due to a virus cause by mosquito. The symptoms appear in 3 to 6 days after mosquito bite. There are three stages of this disease.

- *Stage 1 (infection):* The infected person shows following symptoms in first 3 to 4 days, fever, loss of appetite, headache, joint pain, vomiting and jaundice. After day 4 these symptoms become brief.
- *Stage 2 (remission):* In this stage, most of the symptoms are gone and people can be recovered but due to carelessness the situation can get even worst.
- *Stage 3 (intoxication):* In organs such as liver, heart and kidney different problems may occur [15], [16].

2) Malaria: Malaria is also a disease that happens due to virus by a female mosquito Plasmodium of genus Anopheles carry. If this disease is not treated in time it may lead to complications towards death. There are two types of malaria in general: simple and severe. Simple malaria is curable if treated within time while severe malaria may lead to death.

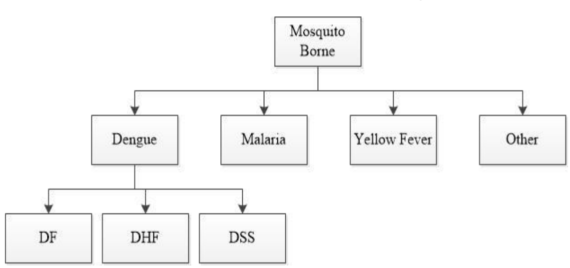

Fig. 3. Mosquitos borne diseases.

Signs and Symptoms:

- *Simple Malaria:* This disease remains for 6 to 10 hours. Its symptoms are, cold stage that has sense of shivering, hot stage with headache and vomiting and sweating stage. Attacking schedule is with Tertain parasite, it occurs every second day & with Quartan parasite it occurs every third day. General symptoms are: Fever, Headache, Sweating, Vomiting, Body ache and Chills. The physical impact of malaria can be seen on the infected body that includes, getting sweaty, temperature rise up, mild jaundice, respiration increased and weakness in body.
- *Severe Malaria*: During simple malaria if there arise a complication of infection in any part of body by failure of any organ it may create severe malaria.

3) Dengue: Aedes aegypti is certain type of mosquitos that causes of Dengue. It is a viral disease and the virus is single-positive strand RNA virus and commonly found in sub-tropical and tropical regions [17].

Signs and Symtoms:

Major symptoms of Dengue are high-fever and combination of at least two which are, Pain in joints, Bleeding gums, Rashes on skin, Very low white-blood cells, Pain in bones and severe pain behind eyes. To get better a proper lookout is very necessary because after 3 to 7 days following things can happen, Red spots on body, Pale skin, Drowsiness, Pain in abdomen, Breathing in difficult. Dengue fever that stays for 2 to 7 days is normally called Dengue Hemorrhagic Fever (DHF). DHF warning appears when after 24 to 48 hours fever suddenly drops and at this time bleeding is started, due to this circulatory system is disturbed and it may lead to death [18].

World Health Organization (WHO) has worked on the Dengue risk factors that play the pivotal role in the disease diagnosis [19]. Similarly, resources have showed that Dengue is assorted disease, its symptoms are mixed with other diseases that make its detection and diagnosis more difficult [20].

IV. RELATED WORK

A. *Expert System using ANN*

In this paper, SOM (Self Organization Map) was used to distinguish between healthy and Dengue infected patients. The research consists of two maps, one that contain BIA (bio impedance analysis) factors and other contains disease symptoms. The research resulted these major BIA factors; Abdominal pain, Anorexia, bleeding and rashes that were present in Dengue patients. After BIA analysis, they found 100-unit best map size with error of 0.033 and quantization error of 1.313 [21]. Goal was to predict occurrence of Dengue by comparing weights. The learning rate varied from 0.5 to 0.9 [22]. Table 2 demonstrates advantages and disadvantages of expert systems by using artificial neural network.

TABLE II. ADVANTAGES AND DISADVANTAGES OF EXPERT SYSTEM USING ANN

Advantages	**Disadvantages**
Reprogramming is not needed	Proper training is needed to operate
Tasks are completed by adjusting weights	Large data, high processing time
Learning is by hit and trail	Complexity is large if data is big
Easy to use and learn by examples	Lack in history maintenance
Perform functions that a linear system can't perform	Highly dependent on data

B. *Emerge*

This is rule-based expert system which was developed to assist in emergency room. This system uses weighting factors determined by neural network. It is composed of input & output block and a hidden layer block that communicates input to output. Neural Network learns from example & predict an output based on this knowledge. It uses IF-THEN-UNLESS instead of IF-THEN that make more precise decision [29].

C. *Expert System using Rule based Reasoning*

Here, Dengue was detected using Rule Based Classifier that are: Decision Tree, Naïve Bayes & Associative Classifiers. The research proved that result from more than one classifier is better than results by using one classifier. The result jumped up to 70% by using more than one classifier thus giving better result than single classifier [23]. In this paper, a Dengue diagnosis system was proposed that observe medical record procedures. It uses tree like model rather than DF and DHF. Out of the record of 41 infected 27 were classified DF, 9 were DHF-I and 5 were DHF-II [24]. Table 3 provides different advantages and disadvantages of expert systems by using rule based reason.

TABLE III. ADVANTAGES AND DISADVANTAGES OF EXPERT SYSTEM USING RULE BASED REASON

Advantages	**Disadvantages**
Representation of knowledge is natural	Knowledge range is narrow
Knowledge is kept separately	Cost effective expert system
Training is used to increase skills	No creative solutions
There is no overhead	No proper rules
Additional help is involved	Can't learn itself

D. *MYCIN*

MYCIN was one of the earliest diagnosis systems that used to diagnose infectious diseases caused by bacteria. First it describes the infection produced by bacteria then, it suggests antibiotic to give the infected person based on the decision [34].

E. *PNEUMOCONIOSIS X-RAY Diagnosis Expert System*

This expert system was developed by Miriam Kubiska and Julie Herzner in 1992. The system has inference engine to examine the shadows on the x-ray. These shadows are used to determine the degree and type of PNEUMOCONIOSIS that is a lung disease. System includes the following:

- The knowledge base that contain data of x-ray representation.
- The interface that details the conclusions.
- Knowledge acquisition mode that allow user to add or change information.

F. *XDIS*

XIDS had information of more than 250-300 internal diseases and syndromes that are frequently met in practice which help experts in diagnosis. The system has instructions for each disease, if disease is curable the system will prescribe medicine but if it is unable to identify the disease it will refer to a specialist. This process takes no more than 10 minutes [29].

G. *Expert System using Integration of Rule base and ANN*

There is also a hybrid technique in which inference engine is updated and maintained whenever a new rule come. The purpose of new rule is to refining of time complexity and efficiency of symbolic rule. The authors explained about neural composition and how they can be shaped directly from results of experiments. Also, they explained the pattern based methodologies in comparison with Rule Based Cases [26]. The expert system was also available on mobile application. The data represented in form of decision tree & cases were stored in table in symbolic form. They maintained database for cases and rules which show that hybrid approach make system faster and always available due to web [27].

H. *Role of Ultrasound in Dengue Detection*

In this paper, the authors perform a study using ultrasound rays to find that can be used to diagnose Dengue fever and also to be useful in predicting the severity of this disease. To test the study 128 people were taken as a subject that suffer Dengue disease. 40 people were identified to be positive case of Dengue, remaining underwent ultrasound again until those who were infected were differentiated from those who were not infected by Dengue virus. They found that after 5 to 7 days of ultrasound effect their gall bladder wall that got thick and had pleural effusion and ascites. They concluded that in epidemic of Dengue ultrasound can be used for diagnosis of Dengue fever [28]. Table 4 presents detail comparison of various expert systems and also express future guidelines for new researches.

TABLE IV. COMPARISON OF DIFFERENT EXPERT SYSTEMS PROPOSED BY DIFFERENT RESEARCHERS

Expert System	**Targeted Diseases**	**Expert System Technique**	**Expert System Methodology**	**Future Guidelines**	**Advantage**	**Limitations**
Medical Expert Solution (MES) system [29]	Tropical Diseases like Dengue Fever , Malaria	1. Inference engine 2. Knowledge Base	MES consist of two main sections: 1. User-interface: This module used for Displaying information and perform user interaction with system 2. Expert system: It consists of inference engine and Knowledge Base. Knowledge Base consist of two elements, Diseases and their symptoms. MES use this data for diagnosis the diseases	1. Enhance Knowledge Base for getting accurate results.	1. Beneficial for those people who don't have excess to medical facilities. 2. Provides first aid facility before going to medical consultant. 3. Reduce physicians work. 4. It can be used in epidemics and war environment.	1. Training required to use the system.
Adaptive Neuro-Fuzzy Inference System (ANFIS) [30]	Dengue , Dengue Fever , Malaria	1. Fuzzy inference system 2. Hybrid learning algorithm for ANIS	1. Optimization of ANIS structure 2. Optimization of hybrid learning training parameters 3. Evaluation of optimal models performance	1. Develop such kind of system which can be used by physicians in hospitals or clinics.	1. Diagnose risk in Dengue patients. 2. It has better performance as compare to noninvasive system which is developed for diagnosis risks in Dengue patients [32]. 3. Diagnostic accuracy achieved up to 86.13%. 4. More robust and reliable than Ibrahim et al. [32]	1. Not practically implemented yet. 2. No module for physicians.
Adaptive-Network-Based Fuzzy Inference System (ANFIS)[31]	Dengue , Dengue Fever	1. Fuzzy if-then rules or fuzzy conditional statements 2. fuzzy-rule-based systems	1. Architectures and learning algorithms 1.1 Architecture and Basic Learning Rule 1.2 Batch (Off-Line) Learning 1.3 Pattern (On-Line) Learning 2. Adaptive-network-based fuzzy Inference system 2.1 ANFIS architecture 2.2 Hybrid learning algorithm 2.3 fuzzy inference systems with simplified fuzzy if-then rules		1. The System proposed new fuzzy models for data classification and feature extraction. 2.Fixed structure of ANFIS.	1. Training issue regarding overlapping between adjacent membership functions and minimal Uncertainty.
An Application of expert system (AExS) [33]	Varicella (Chickenpox), Dengue Fever Hands-foot-and-mouth disease Epidemic parotitis (Mumps)	1.Forward chaining 2. Rule-base system	1. User-interface 2. Inference mechanism 3. Explanation facility 4. Knowledge acquisition facility	1. Construct AExs for large computer program. 2. Web portal design for easy excess of user anywhere.	1. It is important for diagnosis of viral infections. 2. Provide feedback in explanation component and inference engine. 3. Complete system with experimental results.	1. User can only select predefined symptoms. 2. Lack of self-inference ability.
Web-based Patient Support System[35]	Dengue, Diabetes	1. Artificial Intelligence in Medicine 2. Fuzzy logic 3. Neural Network 4.Centralized Databases and WWW	1. WEB-BASED MEDICAL DIAGNOSIS AND PREDICTION 1.1. User-interface 1.2. Predication modules 1.3. Diagnosis modules 1.4. Database	1. Developed distributed databases for improving quality of treatment and providing better diagnosis.	1. Artificial intelligence used to make consultancy more interactive. 2. Fuzzy logic used in uncertainty conditions. 3. ANN produce better results. 4. Provide Tele-health care.	1. Not deployed in working in environment. 2. Lack of experimental study.
Rule based expert system[36]	Dengue infections	1.Bioelectrical impedance analysis (BIA)	1. Development of a rule based expert system 1.1 Identifying the problem 1.2 Tree Diagram 1.3 Rule Based Expert System 1.4 Architecture of the Expert	1. Applying nonlinear modeling technique for improving classification	1. Perform Risk classification in DF and DHF.	1. Do not recognize complex patterns.

			System 1.5 Structure of the Patient Database	accuracy like ANN.		
Predicting arboviral disease emergence using Bayesian networks [37]	Dengue virus	1. Bayesian Belief Network (BBN)	1. Framework and process of BBN risk modelling and Mapping 2. Input data processing and classification 2.1 Climatic parameters 2.2 Road and railroad density 2.3 Seaports and airports 2.4 Human population density 2.5 Frequency of DENV introduction 2.6 Inclusion of endemicity risk node 3. Infection risk under current summer and winter Climates 4. Scenario modelling 5. Sensitivity analysis of risk node	1. Case study done on a large region and get better results for predicating Dengue virus risk. 2. By using this model other diseases like Chikungunya, Yellow fever, and Zika virus can be predicted.	1. Identify Dengue risk in different environments. 2. Dengue virus risk model developed which predict Dengue risk in particular condition.	1. Case study perform only for specific region.
The Integrated Management of Health Care Strategies and Differential Diagnosis [38]	Malaria, Typhoid fever, Cough	1. Combination of Integrated Management of Child illnesses (IMCI) and Health Information Systems (HIS).	1. Action and disease oriented differential Diagnosis of malaria and typhoid fever 2. Knowledge engineering 3. IMCI/HIS expert system interface architecture 4. System evaluation	1. Adaptive interfaces can be designed for urban and rural area users. 2. Provide support for distributed environments.	1. Used for diagnosis Malaria and Typhoid fever. 2. Used in rural area health care where maximum people are illiterate. 3. Provide user-interface for user interaction. 4. Reduce child mortality rate in rural areas.	1. It is stand-alone application which cannot be run in distributed environments.

V. Discussion and Conclusion

Dengue is a viral disease produce by Flavivirus. It has two forms: one is Dengue fever and second is Dengue hemorrhagic fever. DHF is more severe form of Dengue. It has become worldwide major problem in recent years. The expansion of Dengue fever is because of uncontrolled population and urbanization without suitable water administration. If infected female Aedes mosquitos bite human than Dengue virus transmitted in human blood. In computer science, systems that can solve a specific problem and can reason rationally are known as Expert Systems. These systems require knowledge of the relevant problem and techniques to infer the result in order to make decision. In recent years, different researchers have proposed different expert systems for identification, prescribe medicine and overcoming Dengue disease. These expert systems use different technique for getting better result like Bayesian Belief Network (BBN), Artificial Neural Networks (ANN), Fuzzy inference and Hybrid learning algorithm for ANIS.

For implementing these techniques different researchers have proposed different methodologies for determining Dengue patient's problems. The main common strategies in these methodologies are User-interface, Knowledge base engineering process and system evaluation process. User-interface works as bridge between system and user. During designing of user interfaces careful analysis of user tasks and context must be done [40]. We suggest that user interfaces should be well formed to convey knowledge according to user mental model so that a friendly communication may be done between user and system. Mostly knowledge Base consist of two elements, Diseases and their symptoms which can be used for determining disease and predict medical suggestions related to particular disease. We find during study that knowledge base has limited expressive power. Knowledge base should update itself according to environment as if it faces a new symptom which is not added in knowledge base than it should automatically be added in the knowledge base. Knowledge base should be supported for distributed environments. System evaluation used for checking the performance of expert system. A generic mechanism required for evaluation which can be followed by every researcher during designing of expert systems. Globally define certain set of rules to evaluate the expert system.

VI. Future Work

Furthermore, we can enhance Knowledge Base of expert systems for getting accurate results. Such kind of system should be developed which can be used by doctors and patients in web portal. Distributed databases should also be developed for improvement of quality of treatment and to provide better diagnosis. The expert system should be updated as it may be used for other diseases like Chikungunya, Yellow fever, and Zika. Adaptive interfaces should be designed for both literate and illiterate users which would help them to use these systems more easily and efficiently. Online assistance provided to semiliterate users during use of expert system can enhance their performance [42]. Ahmad, N. [41] introduced a new approach which use a virtual character for providing assistance to barely literate or deaf people. By using such kind of support, we can enhance expert system utility by offering additional services like automatic translation from text to sign language.

Finally, autistic people are very sensitive and information technology is very useful for resolving their problem [43]. Therefore, expert system can be designed for autistic people because they also don't know how to react in this situation.

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Evaluating Urdu to Arabic Machine Translation Tools

Maheen Akhter Ayesha[1], Sahar Noor[2], Muhammad Ramzan[3], Hikmat Ullah Khan[4], Muhammad Shoaib[5]
[1,2,5]Department of Computer Science, COMSATS Institute of Information Technology, Sahiwal, Pakistan
[3]Department of CS & IT, University of Sargodha, Sargodha, Pakistan
[4]Department of Computer Science, COMSATS Institute of Information Technology, Wah Cantt, Pakistan

***Abstract*—Machine translation is an active research domain in fields of artificial intelligence. The relevant literature presents a number of machine translation approaches for the translation of different languages. Urdu is the national language of Pakistan while Arabic is a major language in almost 20 different countries of the world comprising almost 450 million people. To the best of our knowledge, there is no published research work presenting any method on machine translation from Urdu to Arabic, however, some online machine translation systems like Google[1], Bing[2] and Babylon[3] provide Urdu to Arabic machine translation facility. In this paper, we compare the performance of online machine translation systems. The input in Urdu language is translated by the systems and the output in Arabic is compared with the ground truth data of Arabic reference sentences. The comparative analysis evaluates the systems by three performance evaluation measures: BLEU (BiLingual Evaluation Understudy), METEOR (Metric for Evaluation of Translation with Explicit ORdering) and NIST (National Institute of Standard and Technology) with the help of a standard corpus. The results show that Google translator is far better than Bing and Babylon translators. It outperforms, on the average, Babylon by 28.55% and Bing by 15.74%.**

Keywords*—*Natural language processing; machine translation; Urdu-Arabic Corpus; Google; Bing; Babylon; translator; BiLingual Evaluation Understudy (BLEU); National Institute of Standard and Technology (NIST); Metric for Evaluation of Translation with Explicit ORdering (METEOR)

I. Introduction

Urdu is the national language of Pakistan while Arabic is a major language in almost 20 different countries of the world comprising almost 450 million people. Among 7,105 languages spoken in different areas of the world, Urdu is ranked at 19th number.[4] In Pakistan, Urdu language is the medium of instruction in most of the public and private institutions. The main information sources such as newspapers and electronic media use Urdu language [1]. Arabic is the main language in 20 different countries like Egypt, Iraq, Saudi Arabia, Somalia, Sudan, Syria and the United Arab Emirates [2]. Arabic is also considered as a religious language of Muslims, as the Holy Quran and Hadith books are written in Arabic language.

Machine Translation (MT) is a process of translating a given input or source sentence from one language to the other target language. Now-a-days MT plays a significant role in different areas like education, business, medical and trade, etc. Different MT techniques such as Rule-based [3], [4], Direct [6], Transfer [5], Statistical [6], Interlingua [7], Example based [8], Knowledge-base [9] and Hybrid Machine Translation [10], [11] (MT) are used to translate from one language to the other.

All the approaches have their own pros and cons. No MT approach is the perfect in all scenarios and for all languages [12]. In this paper, we use the terms “translator”, “MT system” and “MT tool” interchangeably.

A. Motivation

Pakistani and Arab communities have many things in common like cultural heritage, religion, traditions, etc. These communities need to understand each other for many reasons. A large community of Pakistani people works in Arab countries. Every year, a large number of Pakistani people travels to Arab countries to visit sacred places (Makkah, Madina), to get jobs and to promote their trade and businesses. The Arab people also visit Pakistan to get higher education and to promote their businesses. These communities need to understand each other, but there is a language barrier. Machine translation systems can help them remove this barrier. The performance of online MT systems differs a lot. A user of these MT systems may not know the best one. We, in this paper, evaluate the performance of three online MT systems to help the Arab and Pakistani communities to select the best MT system.

B. Problem

Many MT approaches have been proposed in literature for the translation of different languages. In the relevant literature, we could not find any published machine translation approach from Urdu to Arabic however some commercial machine translation systems like Google, Bing and Babylon provide Urdu to Arabic translation. The users of these translators, while translating from Urdu to Arabic, do not know the quality (accuracy level) of their translations. The users may be interested to use the best translator but they might not know the best one.

C. Contribution

In this work, we compare three online MT systems (Google, Bing and Babylon). We evaluate these MT systems by three different evaluation measures BLEU [13], METEOR [14] and NIST.[5] The results show that Google translator is better than Bing and Babylon translators. To the best of our

[1] https://translate.google.com/
[2] http://www.bing.com/translator
[3] http://translation.babylon-software.com/
[4] http://www. ethnologue. com
[5] https://www.nist.gov/

knowledge, our work is unique and the first instance of comparing the Urdu to Arabic MT systems.

Rest of the paper is organized as: Section 2 reviews related work; Section 3 formulates the problem; Section 4 describes the research methodology used for evaluation; Section 5 presents and discusses the results achieved and Section 6 provides summary and potential future work.

II. Related Work

In literature, human, automatic and embedded evaluations are three main types that are used to evaluate MT systems [21]. Many automatic techniques like BLEU, NIST and METEOR are used to evaluate the output of the MT systems. BLEU and NIST techniques overlook the linguistic characteristics of the targeted natural language because both are language independent. Ying et al. in [22] use phrases and identical words that are found in reference translation. An N-gram co-occurrence algorithm is used in their study for producing virtual translations in both techniques. METEOR uses a score based computation in finding similar words between the output of any machine translator and the reference translation given to it. Lavie et al. [23] research shows that the evaluation based on recall used in METEOR having more consistency as compared to that of precision.

As mentioned earlier, there is no research work which targets the content to be translated from Urdu to Arabic therefore we here review some research works which are related to Urdu or Arabic but the translation is aimed for other languages. Different comparative studies of MT systems from Urdu to other languages and vice versa are available in the literature [15]. Same is the case of comparative studies of MT systems from Arabic to other languages and vice versa [11], [16]-[18].

Kit and Wong [16] compare five translators (Google, PROMT[6], SDL[7], SYSTRAN[8] and WorldLingo[9]) using 13 languages (Arabic, Chinese, Dutch, French, German, Greek, Italian, Japanese, Korean, Portuguese, Russian, Spanish and Swedish) with BLEU and NIST scores. They use two reference texts i.e., Universal Declaration of Human Rights and European Union's Treaties. According to their report, SYSTRAN is the best for many languages, especially from Greek and Russian to English translation, whereas Google translator is the best in Arabic and Chinese to English translation. PROMT works better from Portuguese to German, and WorldLingo from Swedish to English than others.

Aiken and Wong [19] compare four translators (SYSTRAN, SDL, WorldLingo and InterTran[10]) using 20 Spanish phrases from an introductory textbook into English. They use human evaluators as reference translation and manually compare the translator results. According to their report, SYSTRAN and WorldLingo are better than SDL and InterTran. Vanjani et al. [20] compare SYSTRAN translator with an expert and intermediate human translator using 10 English sentences. According to their report, the fluent human translator accuracy is 100% and other's 80%. Whereas SYSTRAN got only 70% accuracy while it is faster than human by 195 times.

For Arabic to English MT, Hadla et al. [11] present the comparison of Google and Babylon Translators. The Arabic sentences are categorized in four basic sentences: imperative, declarative, exclamatory and interrogative. They report that Google translator outperforms Babylon translator. Their work is close to ours'. We perform comparative study of MT systems from Urdu to Arabic and they compare the MT systems from Arabic to English.

III. Problem Statement

There are few commercial translators that provide this translation. The users of these translators need to know the accuracy level of these translators. If it is known the users will prefer the best translator.

We formally define our problem as: *"Given the set of Urdu sentences as input to three machine translation systems, compare the output of these translators (Arabic sentences) by using multiple evaluation methods."*

Research Question: Which machine translation system is the best out of the three translators?

IV. Methodology

We compare three online machine translation systems (Google, Bing and Babylon). We use Urdu sentences as input while Arabic is output of the MT systems. The output is compared with the corresponding reference sentences (Arabic). The reference sentences are the true values or ground truth as they are manually translated by the language experts. Fig. 1 depicts the framework of the proposed methodology.

In the following subsections, we describe the corpus and the evaluation methods used in this work.

A. Corpus

We use the corpus[11] exploited by Kabi, et al. [17]. The original corpus contains Arabic and corresponding English sentences. We use all the Arabic sentences available in that corpus and corresponding Urdu sentences. We amended the original corpus by manually translating the Arabic sentences into Urdu sentences. Our corpus[12] comprises of 159 Urdu and Arabic sentences of three different types. The summary of the corpus is shown in TABLE I. We use Urdu sentences as input to the translators and, the human translated sentences (Arabic) in as reference sentences. The reference sentences are used to compare the output sentences of the MT translation systems.

The reference sentences are considered to be correct as they are generated by human experts.

[6] http://www.online-translator.com/
[7] https://www.freetranslation.com/
[8] http://www.systranet.com/translate
[9] http://www.worldlingo.com/en/products_services/worldlingo_translator.html
[10] http://transdict.com/translators/intertran.html

[11] https://docs.google.com/spreadsheets/d/1bqknBcdQ7cXOKtYLhVP7YHbvrlyJlsQggL60pnLpZfA/edit#gid=1057233962
[12] https://drive.google.com/open?id=0B-gV0w2HFyC1NlRiUkIzV3F2UUU

TABLE II shows one sample sentence of each type in Urdu and Arabic.

To evaluate the score of the corpus we use different techniques which are discussed in Performance Measures section.

V. PERFORMANCE MEASURES

We exploit three evaluation measures (BLEU, METEOR and NIST) to compare the performance (accuracy) of the three translators from Urdu to Arabic. As a rule, a machine translation that is closer to the reference translation is considered to be more accurate. This is the gist behind the machine translation evaluation methods.

TABLE I. THE CORPUS STATISTIC

Sentence Type	No. of Sentences
Declarative	70
Exclamatory	49
Imperative	40
Total	159

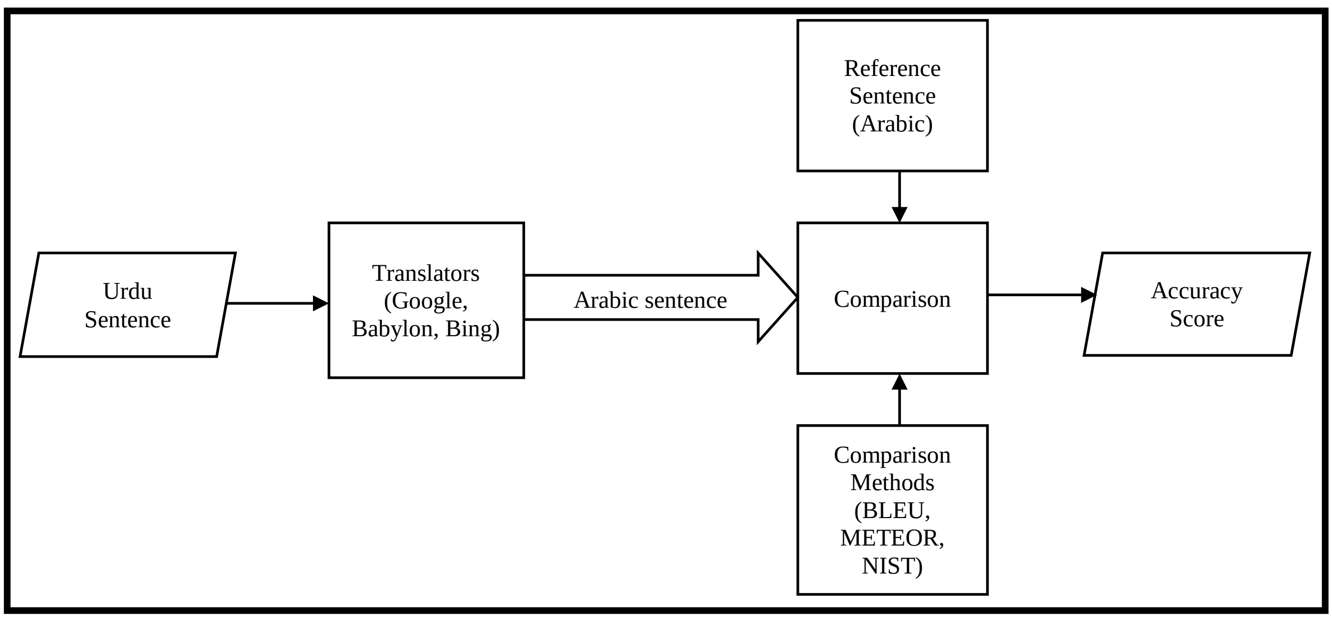


Fig. 1. Block diagram of our comparative evaluation.

TABLE II. EXAMPLE OF ALL TYPE OF SENTENCES USED IN CORPUS

Categories/ Sentence Type	Urdu Source Sentences	Arabic Reference Sentences
Declarative	ملازمین نے ایک لمبی چھٹی لے لی	اخذ الموظفون إجازة طويلة
Exclamatory	کاش وہ وقت پر آجائے!	ليته يحضر على المود!
Imperative	اس کرسی پر بیٹھو	اجلس على ذلك الكرسي

A. BLEU

The BLEU score is calculated by comparing each translated sentence and then comparing with the reference sentence. The average of these scores is computed by averaging them with the corpus size to find the translation accuracy. It is noteworthy that the evaluation does not take into consideration the grammar correctness of the translation. BLEU technique is constructed and put in place to calculate the quality at corpus level. The use of BLEU technique to evaluate the quality of individual sentences always gives an output that lies between 0 and 1. These values tell the readers how similar the reference and candidate sentences (translator output) are. Words with values closer to 1 are closer to the reference translation.

In our case, BLEU divides Urdu sentences into various n-gram sizes, for example, unigrams, bigrams, trigrams and tetra-grams. For each of the four gram sizes, the accuracy for various translators such as Bing, Babylon and Google translator is computed. In the end, for every n-gram sizes, we calculate the n-gram scores of the sentence.

The respective steps to calculate the score for all the n-gram sizes are as follows:

1) Find the total number of common words in every candidate and reference sentence.

2) Then divide their sum over the total number of n-grams in the candidate sentence.

To calculate the BLEU-score these are the steps we need to follow:

1) The first step we need to perform is to calculate the Brevity Penalty (BP) which is calculated by choosing the reference sentence that has the more common *n*-grams length, denoted by *r*.

2) The second step is to compute the total length of the candidate translation, denoted by *c*.

3) Lastly, we need to select the Brevity Penalty to be a reduced exponential in $(r\ /\ c)$ as shown in (1).

$$\mathrm{BP} = \begin{cases} 1 & \text{if } c > r \\ e^{\left(1-\frac{r}{c}\right)} & \text{if } c \leq r \end{cases} \quad (1)$$

$$\mathrm{BLEU} = \mathrm{BP} \times \exp\left(\sum_{n=1}^{N} w_n \log p_n\right) \quad (2)$$

Where, BP = Brevity Penalty; N = Total number of n-gram sizes; w_n = 1/N and p_n = n-gram precision up to N. The final BLEU score can be calculated using (2) and it is based on Brevity Penalty (*BP*) shown in (1).

A higher BLEU score for a machine translation system implies its superiority to other competitors having lower BLEU scores.

B. METEOR

Another machine translation evaluation technique is known as “Metric for Evaluation of Translation with Explicit Ordering” (METEOR). It premises on the harmonic mean of the unigram precision and recall. This technique is different from the one mentioned above in the sense that it works on the segment level while BLEU works on corpus level.

In METEOR algorithm, the first step is to map an alignment between the reference and candidate sentences. This alignment is established according to the unigram technique. Mapping is also considered to be a line between single word of one sentence with the others. Every single word of candidate sentences must map to either zero or one in the reference sentences. If two alignments map on the same word, then we need to consider the one with the fewest one. The final alignment completed by unigram precision (P) is shown in (3):

$$P = \frac{m}{w_t} \quad (3)$$

Where, m = number of common unigrams in candidate translation and reference translation and w_t = number of unigrams in the candidate sentences. After this we compute the unigram recall (R) by (4):

$$R = \frac{m}{w_r} \quad (4)$$

Where, m is same as above and w_r = number of unigrams in the references sentence. We combine precision and recall to calculate harmonic mean as shown in (5):

$$F_{mean} = \frac{10PR}{R + 9P} \quad (5)$$

This technique is only applicable to the unigrams and not for larger segments. To evaluate the n-gram matches, penalty, p as shown in (6) is used to obtain alignment values.

Processing penalty computations and unigrams are combined with one another in possible groups, where these groups are defined as the combination of unigrams. Longer the adjacent mappings between the reference and the candidate sentence, fewer the chunks are. A translation that is similar to the reference translation gives only one chunk. Penalty (p) can be computed by (6).

$$p = 0.5\left(\frac{c}{u_m}\right)3 \quad (6)$$

Where, c = number of unigrams and u_m = number of mapped unigrams. Final METEOR score can be computed as shown in (7).

$$M = F_{mean}(1 - p) \quad (7)$$

The procedure to calculate the METEOR score for the entire corpus is to get the values for P, R and p and then utilize the formula shown in (7).

C. NIST

NIST stands for National Institute of Standards and Technology. Basically, this is a method devised to check the quality of the text. It is similar to the BLEU metric, because it works on n-grams but, at the same time, it is different from BLEU because it does not calculate the brevity penalty. It is similar, to some extent, to METOR as it computes the precision.

We can calculate the score of NIST by using the formula given below in (8).

$$S_{NIST} = \sum_{n=1}^{N} \left\{\frac{\sum_{all\, w_1 \dots w_n\ in\ sys\ output} info\,(w_1 \dots w_n)}{\sum all\ w_1 \dots w_n\ in\ sys\ output}\right\} \times \exp\left\{\beta\ \log 2\left[\min\left(\frac{L_{sys}}{L_{ref}}, 1\right)\right]\right\} \quad (8)$$

Where, L_{ref} = the average number of words in a reference translation averaged over all reference translations; L_{sys}= the number of words in the translation being scored; β is chosen to make the brevity penalty factor = 0.5; N indicates the maximum n-gram length; and *info* $(w_1 \ldots w_n)$ is

$$info\ (w_1 \dots w_n) = \log 2\left(\frac{the\ number\ of\ occurence\ of\ w_1 \dots w_{n-1}}{the\ number\ of\ occurence\ of\ w_1 \dots w_n}\right) \quad (9)$$

VI. Evaluation Through Example

Here we take an Urdu sentence as an example and its reference translation and machine translations from each MT system.

Source sentence: “رشتہ دار دادا کے گھر میں ہیں”

Reference translation: “الأقارب في بيت الجد”

Arabic Translation of MT system is as follows:

- Google: “الأقارب في البيت القديم”
- Bing: “هم الأقارب في بيت آبائنا”
- Babylon: “الاقارب فى منزل جده”

In this example, we see that all MT systems translate the meaning of “رشتہ دار” (“الأقارب”) correctly. For “گھر” Google and Bing matches the reference translation (بيت) while Babylon result is different. All translators give the translation of “دادا” which is not matched with the reference translation.

By calculating the results of above example BLEU score for Google is 0.75, Bing 0.6 and Babylon 0.5. According to METEOR, Google gives 0.75, Bing 0.73 and Babylon 0.5 score. For NIST Google score 2.7, Bing 2.1 and Babylon 1.22. In all the measures, Google is the best in translation as compared to Babylon and Bing.

VII. Results and Discussion

In this section, we repot the results which are generated by our evaluation metrics (BLEU, METEOR and NIST) for the corpus which we mentioned above. We compare the accuracy of each MT system according to three evaluation metrics under separate headings.

A. *Comparison of MT Systems Using BLEU Metric*

In this section, we exploit BLEU score to compare the performance of each translator. TABLE III shows that by applying the BLEU technique on different types of sentences, Google translator gives 0.1675 score, Babylon 0.0645 and Bing 0.1339 BLEU score for declarative sentences. Google performance is better among all the other translators. For exclamatory sentences, Google gives 0.0577, Babylon 0.0315 and Bing 0.0426 BLEU score. For imperative sentences, Google gives 0.1242, Babylon 0.0459 and Bing 0.0586 BLUE score. By calculating the average of all three sentence types, we see that Google gives 0.1164, Babylon 0.0473 and Bing 0.0783 BLEU score. Average values show that Google's performance is more accurate as compared to those of other translators'.

The average results are also shown in Fig. 2. We can easily see that Google outperforms Bing and Babylon. Google translator, as per BLEU evaluation measure outperforms 28.55% better than Babylon and 15.74% then Bing.

TABLE III. BLEU Score of Each Machine Translator

Translator type	Declarative Sentence	Exclamation Sentence	Imperative Sentence	Average
Google MT System	**0.1675**	**0.0577**	**0.1242**	**0.1164**
Babylon MT System	0.0645	0.0315	0.0459	0.0473
Bing MT System	0.1339	0.0426	0.0586	0.0783

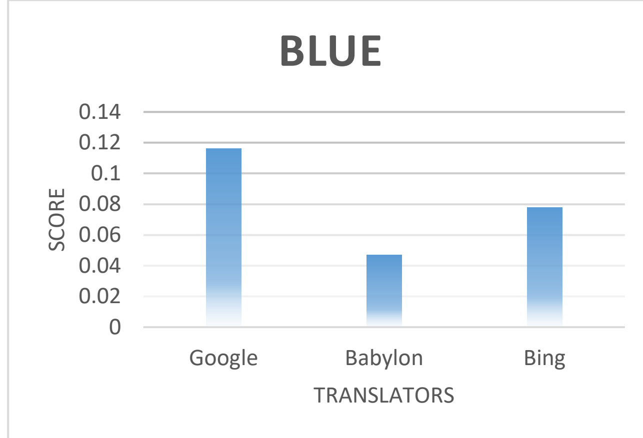


Fig. 2. Comparison of translators by using BLEU metric.

B. *Comparison of MT Systems using METEOR Metric*

In this section, we exploit METEOR score to compare the performance of each translator. TABLE IV shows that by applying the METEOR technique on different types of sentences, Google translator gives 0.21, Babylon 0.1118 and Bing 0.2014 METEOR score for declarative sentences. METEOR scores for Google and Bing are close to each other and better than that of Babylon'. For exclamatory sentences, Google translator gives 0.16, Babylon 0.14 and Bing 0.16 METEOR score. In the case of exclamatory sentences, Google's and Bing's results are exactly same, and Babylon's results are also very near to them. For imperative sentences, Google gives 0.1558, Babylon 0.0871 and Bing 0.1337 METEOR score. Performance of Bing in this type of sentences is near to Google's but Babylon shows poor performance. Averaging the above results, we see that Google's performance is more accurate as compared to the performance of other translators.

TABLE IV. METEOR Score of Online Machines

Type/ Translator	Declarative Sentence	Exclamation Sentence	Imperative Sentence	Average
Google MT System	**0.2100**	**0.1685**	**0.1558**	**0.1747**
Babylon MT System	0.1118	0.1412	0.0871	0.1130
Bing MT System	0.2014	0.1653	0.1337	0.1600

The average results of TABLE IV are also shown in Fig. 3. Google translator, as per METEOR evaluation measure outperforms 13.74% better than Babylon and 3.28% than Bing.

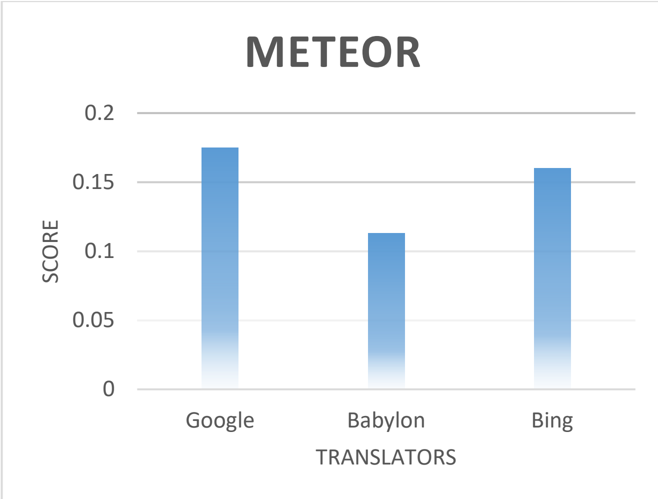
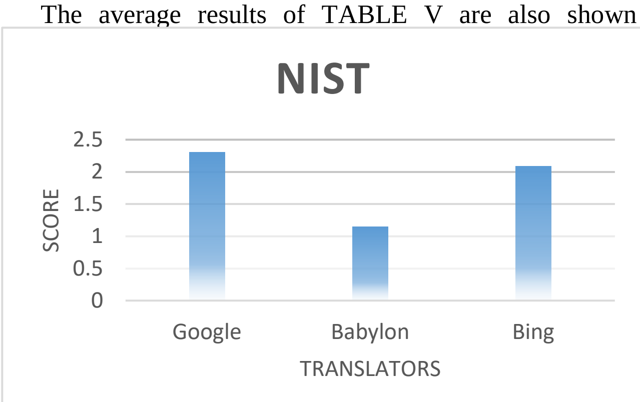


Fig. 3. Accuracy of all online machines using METEOR Technique.

C. Comparison of MT Systems using NIST Metric

In this section, we exploit NIST score to compare the performance of each translator. TABLE V shows performance of MT systems for different types of sentences using NIST metric. TABLE V shows that Google gives 3.14, Babylon 2.0234 and Bing 2.9629 NIST score for declarative sentences. For exclamatory sentences, Google gives 1.5199, Babylon 1.1885 and Bing 1.3881 NIST score. In the case of such sentences, Google and Bing are nearly equal to each other and both are better than Babylon. For imperative sentences, Google gives 2.2591, Babylon 1.3469 and Bing 1.9808 NIST score. Performance of Google in imperative sentences is much better than that of Bing and Babylon. By calculating the average of all sentence types, we see that Google gives 2.306, Babylon 1.151 and Bing 2.089 NIST score. According to this average, Google is the best in accuracy.

The average results of TABLE V are also shown in



. We can see that Google outperforms Bing and Babylon. Google translator, as per NIST evaluation metric, outperforms Babylon by 20.83% and Bing by 3.91%.

TABLE V. NIST SCORE OF ALL ONLINE MACHINES

Type/ Translator	Declarative Sentence	Exclamation Sentence	Imperative Sentence	Average
Google MT System	**3.1489**	**1.5199**	**2.2591**	**2.3060**
Babylon MT System	2.0234	1.1885	1.3469	1.1510
Bing MT System	2.9629	1.3881	1.9808	2.0890

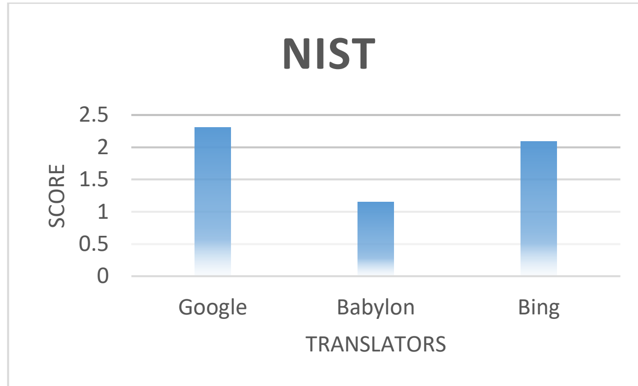


Fig. 4. Accuracy of all online machines using NIST Technique.

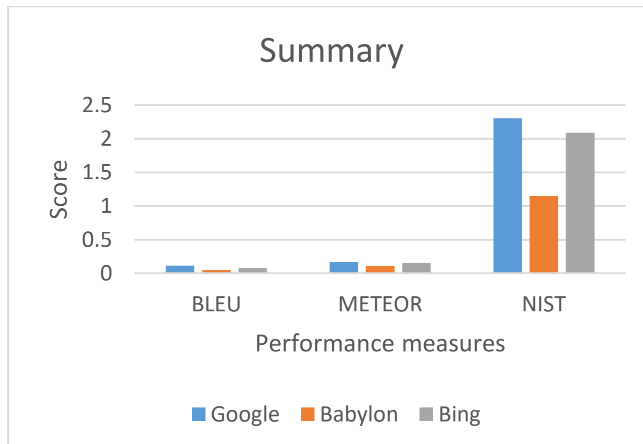


Fig. 5. Summary of tools with respect to evaluation measures.

Comparing results in all techniques BLEU, METEOR and NIST, it is concluded that Google always outperforms Babylon and Bing translators. Fig. 5 shows the summary of all results of all translators w.r.t BLEU, METEOR and NIST metric.

VIII. SUMMARY AND FUTURE WORK

In this paper, we compare three machine translators (Google, Bing and Babylon) for translating Urdu sentences to Arabic sentences by using three performance evaluation metrics (BLEU, METEOR and NIST). The corpus used in this research contains three different types of 159 Urdu sentences and their respective Arabic sentences. Our results show that Google translator, on the average, outperforms Bing and Babylon by 15.74% and 28.55% in BLEU technique, 13.74% and 3.28% in METEOR technique, 20.83% and 3.91% in NIST technique respectively. This study is helpful for those who want to use online machine translators for Urdu to Arabic translation.

We will develop our own Urdu to Arabic machine translation system by exploiting hybrid technique comprising template based and rule based approach. We expect to have better results than the available online machine translators. In future, we will also build a large corpus for evaluation MT systems.

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A Feature Fusion Approach for Hand Tools Classification

Mostafa Ibrahim, Alaa Ahmed
College of Computer and Information Sciences
Al Imam Mohammad Ibn Saud Islamic University (IMSIU)
Riyadh, Kingdom of Saudi Arabia

***Abstract*—The most important functions in objects classification and recognition system are to segment the objects from the input image, extract common features from the objects, and classify these objects as a member of one of the considered object classes. In this paper, we present a new approach for feature-based objects classification. The main idea of the new approach is the fusion of two different feature vectors that are calculated using Fourier descriptors and moment invariants. The fused moment-Fourier feature vector is invariant to image scaling, rotation, and translation. The fused feature vector for a reference object is used for training feed-forward neural network classifier. Classification of some hand tools is used to evaluate the performance of the proposed classification approach. The results show an appreciable increase in the classification accuracy rate with a considerable decrease in the classifier learning time.**

Keywords—Feature fusion; neural network classifier; invariant features; objects classification

I. Introduction

Pattern recognition is a complicated process that consists of many steps, such as image preprocessing, segmentation, feature extraction and patterns classification. The major steps of the pattern recognition process are the feature extraction and patterns classification. Selection of a feature extraction method is probably the single most important factor in achieving high recognition performance [1].

A principal characteristic of pattern recognition problem is that the number of different objects that the system has to cope with is unlimited. That is mainly because of the various shapes of the object, e.g., by varying object scale, orientation and translation. Thus, the problem can't be solved by straightforward template matching. Each object must be classified to one of the pattern classes. The Neural Network (NN) classifier is supervised trained based on a sample of typical objects representing different classes. The classifier then can classify new unknown objects with minimum error.

In the presented paper, we introduce a feature fusion based approach for pattern classification. The proposed fused feature vector consists of reduced Fourier descriptors and four moment invariants. The new approach aims to enhance the classification rate and learning time of the neural network classifier by taking advantage of the inherent complementary of the Fourier descriptors and moment invariants features.

The rest of the paper is organized as follows: In Section 2, the related work is introduced. The proposed work is presented in Section 3. Section 4 presents the pattern classifier. Section 5 shows the experimental results. Finally, the paper ends with the conclusion.

II. Related Work

In literature, there are many image feature extraction methods that have been offered by researchers. These approaches can be categorized into either holistic or local image feature extraction. The first is based on producing statistical information pattern from a big number of training samples of data such as the principal component analysis (PCA) [2]. PCA is improved by many researchers such as 2D PCA [3], block PCA [4], or incremental PCA [5]. Also, matrix decomposition and linear combination are heavily used methods [6]. The holistic approaches have a couple of disadvantages. They don't take into consideration the local detailed information. They are easily affected by the geometric shape changes and noise variation. The local feature extraction methods can prevail over these disadvantages. In [7] authors presented a texture feature description method. It is called a local binary pattern method (LBP). The method is based on computing a binary sequence with 3×3 neighborhoods matrix. The central pixel values are compared to its neighbors and then an LBP histogram is produced as a texture description feature.

The fixed neighborhoods make it easy to restrict the larger neighborhood structure, which is an obvious disadvantage for the LBP method. In [8], [9] authors introduced a region based method with a co-occurrence matrix. This method gives good results especially with medical data sets. To overcome the illumination sensitivity problem, Gabor wavelets filters are considered as a good candidate that could be used in handling this issue. It is an excellent feature representation that is not affected by the illumination or expression variation. In literature, there are a lot of Gabor Extraction methods which give very outstanding results with good performance indicator and ability to work with wide range of applications such as local normalization entropy-like weighted Gabor features [10], Gabor wavelets combined with volumetric fractal dimension [11] and fusion of multi-channels classifier [12]. Neural networks have been extensively used for purpose of objects classification. Among several NN architectures the Back-Propagation model is the most widely used [13]. In [14] authors presented an Extension Neural Network (ENN) for recognizing the tool cutting state. Their results show shorter learning time and better recognition accuracy.

III. Proposed Approach

Fig. 1 illustrates the proposed objects classification process using the feature fusion approach.

A gray scale images are acquired for each object by a digital camera. These gray scale images are then converted to binary images. An object pixel is considered a boundary point if any of its neighbors is classified as background pixel. Tracking the boundary around a pattern is the process of keeping only those pixels that form the boundary of that pattern. This process transforms the two-dimensional binary image into a scalar vector representing the coordinates of boundary points of that pattern. Each boundary is uniquely determined by specifying the location of its initial point and a sequence of points having the same labels as the initial point. Contour tracking have been done using Left Most Looking (LML) algorithm [15]. By taking the Discrete Fourier Transform (DFT) of the object contours, we obtained 16 Fourier descriptors feature vector, which have been handled to become rotation, scale and translation invariant, the same way as described in [16].

A reduced Fourier descriptor feature vector of only 8 descriptors has been computed, by Appling the DFT on the ordinary 16 Fourier descriptors feature vector [17].

Hu's seven moment invariants that are invariant under translation, rotation, and scaling have been calculated from the objects [15], [18]-[20].

$$\phi_1 = \eta_{20} + \eta_{02},$$
$$\phi_2 = (\eta_{20} - \eta_{02})^2 + 4\eta_{11}^2,$$
$$\phi_3 = (\eta_{30} - 3\eta_{12})^2 + (3\eta_{21} - \eta_{03})^2,$$
$$\phi_4 = (\eta_{30} + \eta_{12})^2 + (\eta_{21} + \eta_{03})^2,$$
$$\varphi_5 = (\eta_{30} - 3\eta_{12})(\eta_{30} + \eta_{12})((\eta_{30} + \eta_{12})^2 - 3(n_{21} + n_{03})^2 + (3n_{21} - n_{03}))$$
$$(\eta_{21} + \eta_{03})(3(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2),$$
$$\varphi_6 = (\eta_{20} - \eta_{02})((\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2) + 4\eta_{11}(\eta_{30} + \eta_{12})(\eta_{21} + \eta_{03}),$$
$$\varphi_7 = (3\eta_{21} - \eta_{03})(\eta_{30} + \eta_{12})([\eta_{30} + \eta_{12})^2 - 3(\eta_{21} + \eta_{03})^2] + (3\eta_{12} - \eta_{30})(\eta_{21} + \eta_{03})$$
$$X(3(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2), \quad (1)$$

Where, η_{pq} is the normalized central moment of order (p+q)

$$\eta_{pq} = \frac{\mu_{pq}}{\mu_{00}^{w}}, w = \frac{p+q}{2} + 1 \quad (2)$$

and μ_{pq} is the central moment of order (p+q). For binary pattern G is defined as

$$\mu_{pq} = \sum_{G}\sum (x - x_c)^p (y - y_c)^q \quad (3)$$

Where, (x_c, y_c) are coordinates of the center of gravity of pattern G and are defined as:

$$x_c = \frac{m_{10}}{m_{00}}, \quad y_c = \frac{m_{01}}{m_{00}} \quad (4)$$

Where, m_{pq} is the regular geometric moment and for binary pattern G defined as:

$$m_{pq} = \sum_G x^p y^q \quad (5)$$

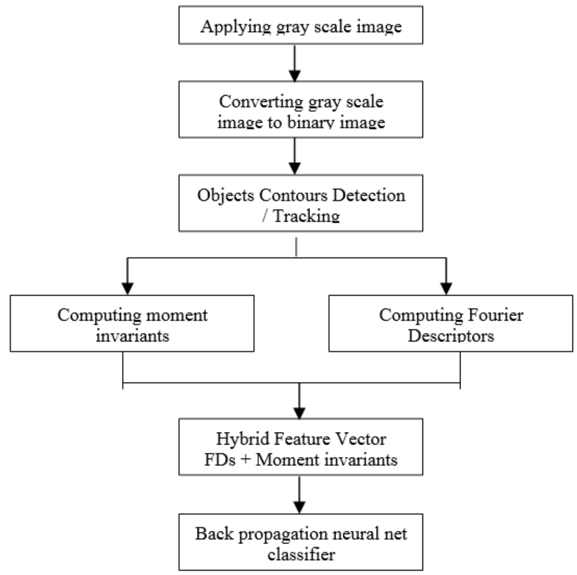


Fig. 1. Proposed objects classification method.

Aiming to enhance the classification accuracy rate and reducing the training time, we developed a new approach for objects classification by combining the moment invariants feature vector with the reduced Fourier descriptors feature vector. Reduced Fourier descriptors are calculated from the object contours while moment invariants are calculated from the objects body. Thus, the fused feature vector is developed to achieve higher classification accuracy rate and reliability by taking advantage of the inherent complementary of the two feature extraction methods. We have used the first four moment invariants ($\phi1$, $\phi2$, $\phi3$ and $\phi4$) in addition to the eight reduced Fourier descriptors resulting in a fused feature vector of 12 coefficients.

IV. Neural Network Classifier

The Feed-forward neural network is the most frequently used among many neural network paradigms, which satisfy the requirements of pattern classification [18], [21]. A Feed-forward neural network, consisting of an input layer, a hidden layer, and an output layer, is considered as shown in Fig. 2. The input layer has 8, 7 and 12 nodes in case of reduced Fourier descriptors, moment invariants and fused feature vectors respectively. The hidden layer has 6, 4 and 8 nodes in case of reduced Fourier descriptors, moment invariants and fused feature vectors, respectively. While the output layer has only three nodes. Each processing element (neuron) is connected to all those in the adjacent layers. The Sigmoid function is used as node transfer function.

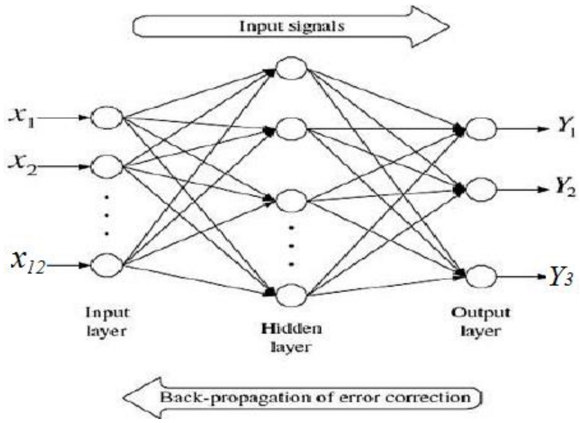


Fig. 2. Neural network classifier using proposed fused feature vector.

We have considered four kinds of hand tools as training patterns; so three output nodes are sufficient as they can represent up to eight different patterns. The output should be (001) for pattern number 1, (010) for pattern number 2, (011) for number 3 and so on. For the neural network training, we have applied "back-propagation learning algorithm" with momentum. All the weights are initially set to random values with a uniform distribution over [-0.5, 0.5]. The patterns in Fig. 3 have been used as training patterns. The training error in case of using any of the feature vectors found to be < 0.0001 with learning rate of 0.5 and momentum term of 0.7.

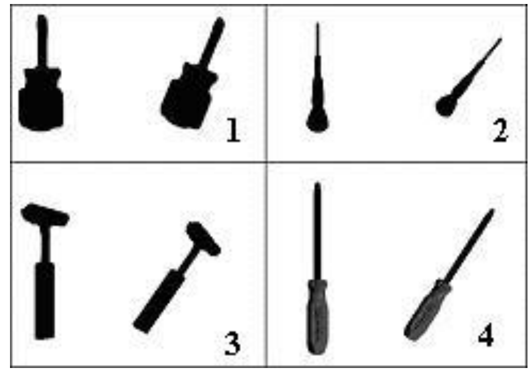
For classifying of the test patterns, we have defined an output vector {out (1), out (2), and out (3) } by thresholding neural net outputs zi in such a way that for i = 1, 2, 3

$$out(i) = \begin{cases} 1 & \text{for zi } \geq 0.9 \\ 0 & \text{for zi } \leq 0.1 \\ unknown & \text{for } 0.1 < z_i < 0.9 \end{cases} \quad (6)$$

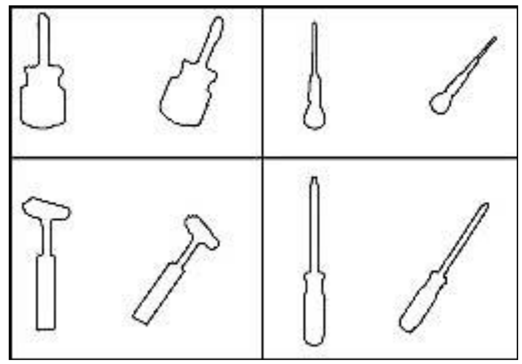
V. Results

This section represents the conducted experimentations along with their results. Two experiments have been conducted. The first is to recognize hand tools. While the second experiment is to recognize rotated and scaled version of these hand tools.

The first experiment is to classify some hand tools without any variations in scale, rotation or translation. As a sample for this experiment four objects have been assigned as shown in Fig. 3(a). First, the objects contours have been detected and tracked as shown in Fig. 3(b). Second, the ordinary Fourier Descriptors (FDs) and the reduced FDs feature vectors have been calculated as indicated in Table 1. Then, we calculated the seven moment invariants and the hybrid feature vector as shown in Tables 2 and 3, respectively. Finally, the feature vectors that were extracted using the above-mentioned methods have been applied to a back propagation neural network classifier.



(a)



(b)

Fig. 3. Training set of objects, 2 samples per object. (a) Training objects. (b) Training object's contours.

TABLE I. Reduced Fourier Descriptors Feature Vectors

	Object-1		Object-2		Object-3		Object-4	
F1	0.310	0.311	0.240	0.229	0.358	0.309	0.198	0.186
F2	0.276	0.282	0.154	0.145	0.270	0.242	0.154	0.140
F3	0.277	0.279	0.175	0.167	0.295	0.225	0.203	0.182
F4	0.330	0.339	0.170	0.177	0.300	0.231	0.241	0.215
F5	0.033	0.048	0.027	0.012	0.035	0.077	0.063	0.056
F6	0.198	0.188	0.074	0.097	0.128	0.153	0.104	0.103
F7	0.460	0.456	0.178	0.207	0.349	0.294	0.204	0.183
F8	0.255	0.251	0.102	0.120	0.218	0.172	0.123	0.124

TABLE II. Moment Invariant Feature Vectors

	Object-1		Object-2		Object-3		Object-4	
M1	0.296	0.296	0.758	0.780	0.712	0.716	0.978	0.968
M2	0.047	0.048	0.524	0.560	0.437	0.443	0.914	0.895
M3	0.016	0.016	0.280	0.269	0.002	0.003	0.364	0.375
M4	0.009	0.009	0.242	0.235	0.000	0.000	0.337	0.328
M5	0.000	0.000	0.063	0.059	0.000	0.000	0.118	0.115
M6	0.002	0.002	0.175	0.176	0.000	0.000	0.322	0.310
M7	0.010	0.010	0.012	0.012	0.017	0.017	0.011	0.010

No. of I/P Layer Nodes	8	7	12

TABLE III. HYBRID FEATURE VECTORS

	Object-1		**Object-2**		**Object-3**		**Object-4**	
F1	0.542	0.541	0.357	0.354	0.552	0.514	0.318	0.315
F2	0.310	0.311	0.240	0.229	0.358	0.309	0.198	0.186
F3	0.276	0.282	0.154	0.145	0.270	0.242	0.154	0.140
F4	0.277	0.279	0.175	0.167	0.295	0.225	0.203	0.182
F5	0.330	0.339	0.170	0.177	0.300	0.231	0.241	0.215
F6	0.033	0.048	0.027	0.012	0.035	0.077	0.063	0.056
F7	0.198	0.188	0.074	0.097	0.128	0.153	0.104	0.103
F8	0.460	0.456	0.178	0.207	0.349	0.294	0.204	0.183
F9	0.296	0.296	0.758	0.780	0.712	0.716	0.978	0.968
F10	0.047	0.048	0.524	0.560	0.437	0.443	0.914	0.895
F11	0.016	0.016	0.280	0.269	0.002	0.003	0.364	0.375
F12	0.009	0.009	0.242	0.235	0.000	0.000	0.337	0.328

In this experiment, we have examined our classifier by applying the same feature vectors of the objects in Fig. 3(b) that have been used for training the neural net classifiers. The results showed that the recognition rate is 100% in all approaches.

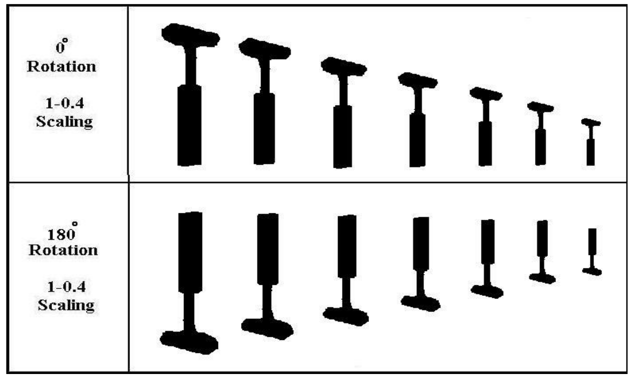
The second experiments evaluate the performance of the proposed objects classification technique with rotated, scaled and translated samples of the reference objects. Fig. 4(a) and (b) show scaled, translated and rotated versions of the objects that have been used in training the neural network classifier to be used as testing sets of patterns. While Fig. 4(c) shows the set of hand tools used for testing.

The first stage in this experiment is to obtain the first 16 Fourier descriptors and the reduced FDs for those patterns, then, use the resulted reduced FDs feature vectors as input to the classifier and record the results of recognition process. The second stage is to obtain the seven moment invariants feature vector and the hybrid feature vector for each pattern to use them as input feature vectors for the neural network classifier, then, records the results of recognition. At last, the results of both stage's recognition rates are compared.

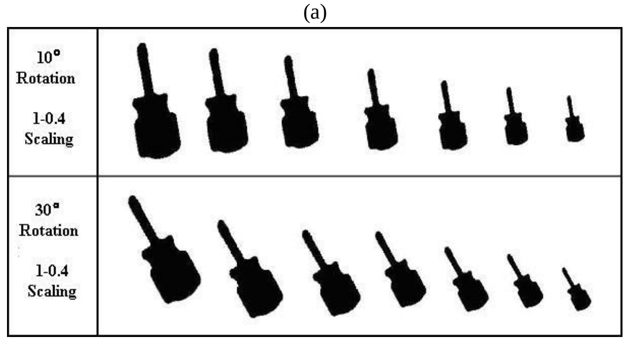
For the performance evaluation of the classifier using the feature vectors computed in first and second stages; a large testing set for each of the target objects was constructed to have seven scale variations from 1.0 to 0.4, for each of 12 rotation angles, a total of 12 rotation angles times 7 scale factors equals 84 testing samples. This results in a testing set of 336 patterns for the four target objects. Table 4 shows a comparison between the recognition rates using the three feature vectors.

TABLE IV. COMPARISON BETWEEN RECOGNITION RATES

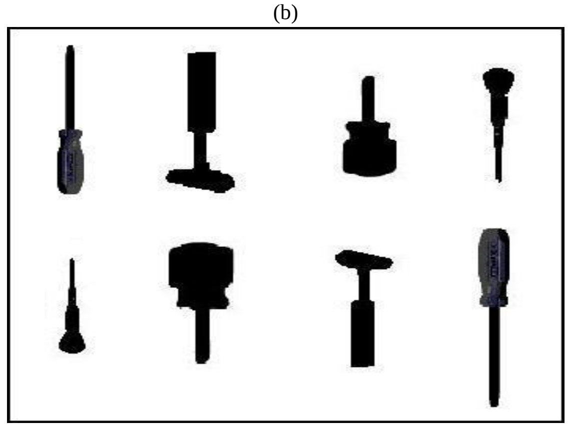
Object	Reduced FDs	Moments	Fused Feature vector
1	97.62%	100%	100%
2	92.86%	92.86%	97.62%
3	97.62%	100%	100%
4	92.86%	92.86%	95.24%
Training time (ms)	3855	2704	1673



(a)



(b)



(c)

Fig. 4. Sample of testing objects set.

VI. CONCLUSIONS

This paper introduces a feature fusion based approach for objects classification. The proposed feature fusion based approach consists of a fused feature vector of four moment invariants and eight reduced Fourier descriptors. The fused feature vector is invariant to object scaling, rotation and translation. A feed-forward neural network has been used as objects classifier. The proposed approach has been applied to recognize and classify four different hand tools. The results show that the use of fused feature vector outperforms the individual use of Fourier descriptors or moment invariants. The results show an appreciable increase in the classification accuracy rate while considerably decrease the classifier learning time compared to the learning time in case of using reduced FDs or moment invariants feature vectors.

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A Survey of Schema Matching Research using Database Schemas and Instances

Ali A. Alwan
International Islamic University Malaysia, IIUM,
Kuala Lumpur, Malaysia

Azlin Nordin
International Islamic University Malaysia, IIUM
Kuala Lumpur, Malaysia

Mogahed Alzeber
International Islamic University Malaysia, IIUM
Kuala Lumpur, Malaysia

Abedallah Zaid Abualkishik
College of Computer Information Technology
American University in the Emirates
Dubai, United Arab Emirates

***Abstract*—Schema matching is considered as one of the essential phases of data integration in database systems. The main aim of the schema matching process is to identify the correlation between schema which helps later in the data integration process. The main issue concern of schema matching is how to support the merging decision by providing the correspondence between attributes through syntactic and semantic heterogeneous in data sources. There have been a lot of attempts in the literature toward utilizing database instances to detect the correspondence between attributes during schema matching process. Many approaches based on instances have been proposed aiming at improving the accuracy of the matching process. This paper set out a classification of schema matching research in database system exploiting database schema and instances. We survey and analyze the schema matching techniques applied in the literature by highlighting the strengths and the weaknesses of each technique. A deliberate discussion has been reported highlights on challenges and the current research trends of schema matching in database. We conclude this paper with some future work directions that help researchers to explore and investigate current issues and challenges related to schema matching in contemporary databases.**

Keywords*—Data integration; instance-based schema matching; schema matching; semantic matching; syntactic matching

I. Introduction

Nowadays, integrating and managing a tremendous amount of data has been extremely simplified due to the advancement in information technology. Several solutions have been proposed to combine data from different heterogeneous sources to form a unified global view. This process, called data integration aim to represent data in one single view and facilitate the process of interacting with the data to be appearing as one single information system [1]. However, it is very challenging to integrate and manage data from several sources that are being independently developed. This is due to the fact that there are different representations of these sources, and data sources might not be designed in a way to adopt the same abstraction principles or have similar semantic concepts to be fully used [2]. Besides, there might be various terminologies used to describe and store information which might negatively influence in the process of integrating the data [3].

Many firms might attempt to integrate some developed heterogeneous data sources where these businesses have various databases, and each database might consist of a vast number of tables that encompass different attributes. The heterogeneity in these data sources leads to increasing the complexity of handling these data, which result in the need for data integration [4]. Identifying the conflicts of (syntax (structure) and semantic heterogeneity) between schemas is a significant issue during data integration. For this reason, schema matching has been proposed to handle the process of discovering the correspondence between schema and resolve conflicts when occurred.

Nevertheless, using schema matching approach is inappropriate when databases are developed separately and without unified standards [5]. Furthermore, it is impractical to employ the schema design information “schema attributes” to determine the correspondences attributes when different abbreviations of attribute names “column’s names” is used to represent the same real world entities or objects [2]-[5].

Consequently, discovering instance correspondences become an alternative approach for schema matching when schema information is not available or insufficient to be used for matching purposes. Instance-based schema matching attempts to extract the semantic relationship between targeted attributes via their values “instance”. Therefore, if the schema matching approach fails to detect the match, then the instances will be looked at to carry out the matching process. In this paper, we surveyed and examined some well-known techniques of instance-based schema matching. We described the strengths and the weaknesses of these techniques and end the paper with some future work directions that can benefit the researchers in the area of data integration.

This paper is organized as follows. Section II presents the schema information levels. Section III presents and explains the classification of schema matching methods and the process of instance-based schema matching. In Section IV, the techniques applied based on instance level matching has been explained. The related works for instance-based schema matching have been reviewed and reported in Section V. The discussion on the topics presented in this paper is reported in Section VI. Conclusion is presented in the final Section VII.

II. Schema Information Levels

Due to the rapid development of information systems, the demand for schema matching solutions is growing dramatically [7], [8]. For example, the role and tasks of the enterprise databases evolved from the traditional use of storing and manipulating data to be an effective tool for data analysis and interpretation. Different heterogeneous databases might need to be integrated for various purposes. The heterogeneity between databases encompasses the structure and the semantic, which have resulted in the necessity of the schema matching [2]. The driving force behind the significant development in database role is due to the complexity in obtaining data from various heterogeneous sources. Besides, the need for intelligent decision supports tools that extract heterogeneous data to ensure the best decision for users. Identifying the correspondences (matches) between database schemas has been commonly referred to as a schema matching problem [6], [7], [9].

There are three types of information that commonly used to solve the problem of schema matching by identifying the semantic of schema attributes and detect the correspondences between database schemas, i.e., 1) schema information; 2) instances; and 3) auxiliary information [9], [10]. Several solutions have been proposed aiming at handling schema matching based on the available schema information [12], [13]. These information help in preventing the incorrect match between schema attributes and lead to detect the similarities between schema attributes, particularly for semantically complex matching process. There are many beneficial levels of information that can be utilized to identify the schema matching. This includes metadata level, instance level, and auxiliary level [2], [10]. Apparently, several approaches have been proposed employed levels of schema information. Some of these approaches rely on utilizing each level independently as identified individual matcher based on their problematic situations and information available [10], [15]. While, other approaches involve a combination of the individual matcher to enhance the matching results [7], [16]. Basically, schema information has been classified into three levels, namely, schema level, instance level, hybrid level and auxiliary level. These schema information levels are further elaborated below:

A. *Schema Levels*

Schema level information consists of three levels of information, which are 1) linguistic level; 2) constraints level; and 3) structure level [16]. Linguistic level uses meta-data information such as the attribute's names or abbreviations and available textual descriptions to find the correspondences between schemas [5], [8], [13]. While, constraint level relies on the data types of the database attributes such as (string, numeric, and char), the ranges of instances, and different types of keys (primary, super, uniqueness) [13], [16]. Lastly, the structure level utilizes the internal and external structure of the schema and the cardinalities between schema attributes [13], [16].

B. *Instance Level*

Instance level information, which is also known as contents level has been extensively applied as an effective tool to determine the correspondence between schemas. In many cases, it is not easy to obtain information from the schema structure as either it is not available or the information is meaningless and could not be used for the matching purpose [5], [10], [17]. Thus, in such cases, instances are considered as the most efficient and reliable source of information to identify the correspondences between attributes and determine the similarities and corresponding attributes of schema based on exploiting the characters of available values/instances.

C. *Hybrid Level*

Hybrid level retrieves information from the combination of both schema metadata (attribute names, data type, structure and description) and instance level (values/instances) [8], [13], [15]. Several criteria and sources of information might be taken into consideration to achieve the matching between schemas. Among these criteria in sources includes name matching and thesauri together with compatible data types that lead to improving the performance through providing best-combined match candidates compared to the individual performance of different matchers [15].

D. *Auxiliary Level*

Auxiliary level information is the process of combing existing schema information along with additional information obtained throughout external sources. Examples of external sources include WordNet/Thesauri, and dictionaries can be used for identifying the semantic relationships between schema attribute names or abbreviations such as synonymy and hyponyms in order to determine the similarities if it exists [5], [13].

III. Classification of Schema Matching Methods

In the literature, there have been many schema matching methods developed with the aim of identifying the match between database tables. There are a good number of surveys that discussed, classified and examined these methods [16], [18]. For instance, E. Rahm and P. Bernstein [11] have suggested a taxonomy that classified the schema matching methods into two categories, namely: individual matcher and combining matchers as depicted in Fig. 1.

For individual matchers, only one single parameter takes into consideration to compute the mapping between instances. Individual matchers concentrate on the available schema metadata (metadata) in terms of integrity constraints, attributes names, descriptions, and schema structures with disregard to the lowest level of information (instance) [16]. It is very common to use schema information to perform the matching between less complex databases, and it is very beneficial in the case of absence of instance level data [8]. In contrast, combining matchers either involves many criteria (i.e. name and type equality) to form hybrid matcher or combines multiple match results from various match methods to form a composite match.

Individual matcher has been predominantly adopted by a considerable number of researches and studies which reflected the trends toward concerning single matcher. Studies conducted by [4], [5], [19] emphasized the essential role of instance level matching (instance matcher) in extracting semantic similarity of schemas. These studies attempt to improve the matching process in different application domains. The application domains include Domain-Specific-Quire, data integration, and mediating databases. Additionally, D. George [20] suggested different classifications of schema matching via data integration approaches. He categorized them into two layers, namely, semantic (meaning), syntax (format), and schema (structure). He argued that there are different kinds of conflicts occurred between database tables, such as naming conflicts and structure conflicts, which is different terminologies used to represent entities or attributes names such as synonyms and homonyms. Structure conflicts that involve several types such as type conflicts, dependency conflicts, key conflicts, and behavioral conflicts. In the following, we examine and discuss the schema matching approaches illustrated in Fig. 1.

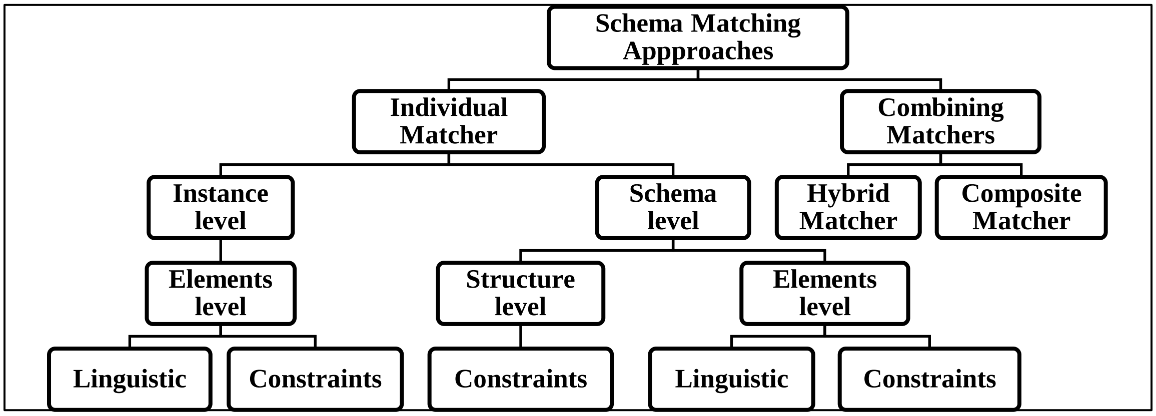

Fig. 1. Classification of schema matching methods.

A. Schema Level Matching

Schema level matching methods utilize the available schema information of the database such as name, description, type of data, constraint, and schema structure in order to identify the match between two attributes of the database schemas. Most often, more than one candidate match might be produced for each candidate, with estimated degree of similarity in the range between 0 and 1. The closer the degree of similarity from one is the more similar. Two levels under schema level matching can be exploited to define the correspondence between attributes, which are element level and structure level. Moreover, there has been a trend to consider the logs query as an additional level of information for schema matching by a number of researchers and studies [6]. This new approach attempts to extract attributes usage of each targeted schema from the logs of queries concerning the schema relationships, and their features such as joins and with aggregate functions [6]. Besides, the click logs have been mainly utilized for keyword queries of an entity search engine in order to determine the terms of the search. This will let to categorize the schema attributes that share similar search queries as candidates' match [16].

1) Element Level Matching

Element level matching aims at employing the elements belongs to the source schema to determine the matching elements of the input target schema. In many cases, it is possible to exploit the schema elements at the finest level, which called atomic level, such as attributes in an XML schema or attributes in a relational schema. An example of atomic-level for the schema fragments is illustrated in Table 1. It can be observed that Address.ZIP ≅ CustomerAddress.PostalCode represents an atomic-level schema matching between S1 and S2 elements [10], [11]. Element level matching also focuses on exploiting two levels that are linguistic matcher and constraint matchers.

a) Linguistic Matcher

Linguistic matcher involves the available linguistic information of the database schemas such as attributes names and descriptions of the attributes in order to determine the match between the schemas [21]. This approach is very common for databases with the centralized environment, where the similarities between attributes names can be described by their meanings. It is also used for semi-structure databases, where schema descriptions are well-defined. The idea of the linguistic match is to transform the attribute's names into a canonical model (form) through the tokenization method in order to compare these names equality [22].

TABLE I. FULL VERSUS PARTIAL STRUCTURAL MATCH

S1 elements	S2 elements	
Address Street City State ZIP	Customer Address Street City USState PostalCode	Full structural match of Address and Customer Address
Account Owner Name Address Birthdate TaxExempt	Customer C nae CAddress CPhone	Partial structural match of Account Owner and Customer

b) Constraint Matcher

Constraints are a very useful facility that most often used on database schemas to define the data types, the range of values, the uniqueness, the relationships types and cardinalities. In many cases, if the source and target input schemas contain a sufficient amount of constraint information, it can help the matcher technique to identify the similarity between schemas and provide a precise match between schema attributes. For instance, the similarity score can be introduced based on many factors such as the similarity of data types or domains. Besides, some key characteristics can also be involved to compute the similarity score, including primary key and foreign key. Furthermore, the relationship cardinality that identifies the level of relationship between the attributes such as 1:1 relationship and of is-a relationships [11], [15], [16]. However, it is not always applicable to use constraint information alone to obtain an accurate matching result. In some cases, constraint information might lead to imprecise match due to the comparable constraints among attributes in the schemas. Nevertheless, exploiting constraints information helps to reduce the number of match candidates and might be combined with other matchers (e.g., linguistic matcher) [2], [11], [15].

2) Structure Level Matching

Structure level matching used the structural information about database schemas to determine the match between schemas. Structure level matching concentrates on the structures and the constraints information about the targeted schemas to extract the similarity between the attributes [24]. There are many possibilities to match combinations of various attributes in a structure, depending on the completeness of the structural information and the required precision. In the ideal case, there should be a full matching of all the attributes of the source and target schemas. However, in some cases, a partial match between some attributes might be introduced, which is needed when there is a comparison of the sub-schemas. Notice the example given in Table 1, where partial match occurred between Account Owner and Customer schemas. It is also possible to use constraint-based matcher as an alternative matcher in this level, exploiting the constraints information such as data types, value ranges, nullability, and referential integrity (foreign keys) [2], [9], [10], [15], [23].

B. Instance Level Matching

Instance level approaches employ the available instances as a source to identify the correspondences between schema attributes. It is not always possible to utilize the schema information to perform an accurate match between schemas. In many cases such as semi-structured databases, information about schema might not be available or limited to be used for precise schema matching result [2], [10], [17], [24]. Hence, for such cases, instances could be used as a source for determining the corresponding of attributes. Instance-level data could be used as a significant alternative source contributing toward accurate matching due to its valuable contents and the meaning of schema attributes.

C. Combination of Multiple Matcher

There are several approaches with many variations of matchers have been proposed in the literature. Each approach has its strengths and weaknesses, and no single approach fits all cases and can give a reliable match. Many attempts have been conducted employing multiple approaches to form hybrid matcher that involves multiple criteria to identify the match between schema attributes. Besides, other approaches endeavor to develop a composite matcher benefiting from the independent matching results produced by different approaches [8], [10], [11]. Hybrid and composite matchers are further explained as follow.

1) Hybrid Matcher

Hybrid match aims at combining several matching approaches in a single approach to performing a precise match between possible candidates, taking into consideration multiple criteria and different sources of information. This includes name matching and thesauri combined together with data types to provide more accurate matching results while maintaining high performance compared with separated individual matchers.

2) Composite Matcher

Composite matcher intends to carry out the independent match on database schemas using different approaches and then combine the outcomes. Doing so allows selection of the most appropriate matchers to be implemented. Composite matcher has a greater flexibility compared to hybrid matcher as it exploits the application domain and input schemas information, while different approaches can be used for structured versus semi-structured schemas [10], [11], [25].

IV. Techniques Applied for Instance Level Matching

Most of the previous approaches for instance based schema matching is designed with the aim of determining the correlations and identify the correspondences between attributes depend on data instances that are more semantically and syntactically [5], [10], [13]. This concern on data instances reflects the fact that we need to utilize a certain technique to explore the semantic and syntactic similarities throughout the matching process [20]. In many real-world database applications, the sources of attributes are developed separately by different developers, which results in differences in terms of syntax and semantics of the schema attributes. This research work examines the most predominant techniques that rely on syntactic and semantic. Syntactic techniques encompass N-gram, and regular expression [2], [14]. While, semantic techniques include Latent Semantic Analysis (LSA), WordNet, Thesaurus and Google similarity [2], [10]. These techniques are explained in further details in the following subsections.

A. Syntactic Techniques

Many schema matching techniques have been developed for the syntactic heterogeneity of the database schemas. Identifying the similarities between different schemas via matching process would not be a trivial task, due to these heterogeneities [13]. In addition, data with numerical values and acronyms are typically described according to certain patterns, which are better suited for syntactic heterogeneity analysis [14]. In this respect, some strategies have been suggested to draw syntactical patterns, and identify related values ranges, for instance-based schema matching [11]. The following subsections demonstrate the details of syntactic techniques that have been utilized widely by previous approaches.

1) N-gram

The N-gram is a model that has been extensively used for different tasks such as spelling correction, word breaking and text summarization and recently for analyzing matching purposes [4]. The analytical process involves the fragmentation of words or texts sequentially into consecutive tokens. As a result, N will be a computer, which represents the possible tokens of the desired word, which are so-called “unigram”, and a string of M letters would subsequently have (M-2) grams. For instance, considering the desired word is “address” and its grams are three sets as the desired word in the matching task. The possible tokens of the word “address” would be denoted as St (“address”) = {add, ddr, dre, res, ess}, where S is a string and t is an integer that represents the word and its length’s set of grams respectively. Similarly, N-gram can be obtained via fragmentations of the characters of strings [5]. Although the N-gram technique is well understood and easy to implement, its reliability is questionable in the case of absence or the lack of a common and shared values between schema attributes [2], [4], [5], [10].

2) Regular Expression

Some studies have suggested the utilization of regular expression in term of instance based schema matching [2], [10]. It is known as RegEx, which defined as a technique that describes both statistical data and texts using pattern recognition concepts to define a specific data path [2]. In fact, for each schema attributes, instances are exposed to define its pattern class, and then schemas are matched based on these patterns classes. Therefore, schemas attributes considered as a match, if they explicitly correspond to the same regular expression of the same class patterns [14]. As a result, this has led to the idea of combing constraint-based with the instance based schema matching for further enhancement of the efficiency and accuracy of the matching results.

B. Semantic Techniques

For semantic techniques, the evaluation criteria are based on both the instances point out to the same definitions of the concepts of the real world entities or represent the same meanings [5], [10]. Different types of semantic heterogeneity of a schema have been defined in the literature such as classes, data sets, and structure [20]. Hence, considerable numbers of techniques that can extract the semantic relationships among schemas have been proposed in the literature. In this research work, we have focused on three techniques, namely, Latent Semantic Analysis (LSA), WordNet/Thesaurus and Google similarity. These techniques have been used most frequently in the literature representing semantic technique due to their accurate results in identifying the match between attributes [26], [27].

1) Latent Semantic Analysis (LSA)

Latent Semantic Analysis (LSA), which is also known as Latent Semantic Indexing (LSI) applies a word-to-word matching called a corpus-based semantic similarity [28]. It is typically performed by considering the occurrences of the words in the corpus over the certain collection of documents [10]. The main advantage of the LSA is the appropriate representative of the synonymy, polysemy, and term dependence over the documents. However, LSA is a lack of efficiency and time constraint. These are because, during the search, the targeted query is compared to every document in the collection, including some terms that do not share in common with the query. Besides, LSA works within a limited number of closed collections of documents [10], [28].

2) WordNet/Thesaurus

WordNet/Thesaurus defined as a huge lexical English language database that has been developed and maintained by Princeton University as the product of a research project drawn up in the home (insourcing). It consists of three integrated sub- databases. These sub-databases contain a variety of English terms including nouns, verbs, adjectives and adverbs grouped into arrays of cognitive synsets (synonyms), and antonyms. One of the advantages of WordNet is the ability to interlink words by their specific senses, and to label the words neatly by writing the word semantic relations [29]. However, it does not produce obvious patterns other than the meaning similarities [29]. On the other hand, the use of WordNet is considered lacks the ability to interpret compound nouns (non-dictionary words), abbreviations or even acronyms [10].

3) Google Similarity

Google Similarity was initially called Google Similarities Distance (GSD). In its application, this technique relies on the largest online databases that contain a tremendous amount of online pages. Its main strength is utilizing the Google engine search methods for establishing the semantic relationships between the phrases and words, while it is applicable to other search engines and database application [30]. The automatic extraction of similarities between words and phrases used online, based on Google page counts results. As a result, the searching task for certain index terms is typically performed by counting the number of hits (where index terms exist via Google pages) [5]. The main advantage of Google similarity distance is the high level of reliability achieved through establishing the semantic relationships between words and phrase, which is based on the actual application of the English language within the society [27], [30]. In addition to the reliable interpretation of semantic, Google distance is more efficient in processing a huge collection of documents, in contrast to WordNet, and LSA [2], [10]. In short, GSD takes advantage of the number of hits returned by Google to compute the semantic distance between concepts. These concepts are represented by their labels by GSD, which are fed to the Google search engine as search terms.

V. Related Work of Instance-Base Schema Matching

Instances-based schema matching has been investigated by numerous studies that concentrate on enhancing the accuracy of the schema matching result. Different approaches have been proposed, adopted various strategies for precise determination of correspondence between attributes of schemas. From the literature, it can be summarized that there are four main strategies that exploited the contents of the database (instances) to detect the correspondence between attributes that leads to schema matching [31], [32]. These strategies are 1) neural network; 2) machine learning; 3) information theoretic discrepancy; and 4) rule based. Hence, this research work further discusses these four strategies that have been used for instance based schema matching.

A. Neural Networks

Neural network strategy relies on utilizing the available instances to generate the similarities among data, and empirically infer solutions from data without using the knowledge about the regularities [10], [33]. The idea of the neural network in identifying schema matching between schemas is as follow. It attempts to create a cluster for those attributes with instances that are uniformly characterized using feature vectors of constraint-based criteria. However, neural network strategy is very specific and domain-dependent and can only be used with that specific domain since it is trained based. In the following, we discuss the previous works related to schema matching based on neural network strategy.

L. S. Wen, and C. Clifton [33] have addressed the issue of schema matching in heterogeneous databases utilizing neural network strategy to determine the correspondences between attributes. The proposed approach attempted to employ both information (schema and instance) to derive the matching rules of the attribute automatically. However, the performance of the approach negatively influenced when using naming-based approach. You, Dong, and Wei (2005) [34] introduce a neural network Schema Matching technique based on Data Distribution (SMDD). SMDD technique attempts to benefit from the analysis of the characteristics of data distribution to capture the correspondences between schema attributes. Furthermore, a Content-Based Schema Matching Algorithm (CBSMA) adopts neural network strategy is proposed in [35]. CBSMA relies on the full discovery of data content to identify the match by first analyzing the data pattern, which is conducted by training a set of neural networks. Then, attempts to extract the identified features and cluster them to get training data and classifying data with Back Propagation Neural Network. K. S. Zaiss [15] introduced two instance based matching methods utilizing neural network strategy. The first method relies on the syntactic facts of the database schema to generate regular expressions or sample values that result into characterizing the concepts of ontology by their instance sets. The second method uses the instance sets to describe the contents of every instance using a set of regular expressions. Table 2 summarizes the neural network approaches for instance based schema matching presented throughout this section.

TABLE II. SUMMARY OF THE NEURAL NETWORK APPROACHES

Author & Year of Publication	**Accuracy**	**Handling Instances**	**Matching Process**	**Technique**	**Matching-based Approach**
L. S. Wen and C. Clifton, (2000)	P = 80%, R = 90%	String and Numeric	Semi	Semantic Integrator (SEMINT)	Semantic
L. You et al., (2005)	F= 0.65%	String and Numeric	Auto	Instance Similarity	Semantic
Y. Yuan et al., (2008)	P = 96%, R = 90%	String and Numeric	Auto	Feature Vectors	Syntactic and Semantic
K. S. Zaiss (2010)	P= 90%, R= 64% (Regular Expression) P=85%, R=66% (Feature Analysis)	String, Numeric and Date	Semi	Regular Expression & Features Matcher	Syntactic and Semantic

B. Machine Learning

In contrast, machine learning strategy develops a solution based on machine learning methods such as Naïve Bayesian classification to produce accurate matching results based on schema information. Typically, machine learning methods use both information (schema and instance) during the matching process. However, machine learning methods need to involve a training data set of correct matches that might require a large training data set to derive the most appropriate matches between schemas. There have been a variety of approaches proposed exploit machine learning methods to learn the instance characteristics of the matching or non-matching attributes and then use them to determine if a new attribute has instances with similar characteristics or not [5], [10], [32], [37]. Doan et al., (2001) [32] proposed a machine learning based system called, Learning Source Descriptions (LSD) that locates attributes matching in a semi-automatic manner. LSD achieved a limited accuracy, in the range of 71%-92% due to the mismatch of some tags, and also some tags need different types of learning because they are ambiguous. The work contributed by J. Berlin and A. Motor [36] introduced a machine learning strategy based approach named Autoplex to identify the match between schema attributes exploiting data instances. However, the experiment result showed that Autoplex performed only 0.81 for both soundness and completeness.

Moreover, learners need retraining when Autoplex applied to a new domain. F. Ji et al. (2009) [7] proposed new instance based schema matching approach based on machine learning strategy. The approach assumes that corresponding attributes are relatively equally important. The work presented by F. Ji et al. (2009) [7] is unlike the traditional approaches, which assumed that all attributes have the same degree of importance. In contrast, the proposed approach employs machine learning methods to prioritizing all schema attributes according to some predefined ranks and classes. However, the approach is suitable only for numeric instances, as the result of precision (P) dropped when string instances are considered [2], [10]. Lastly, the work contributed by M. A. Osama et al., (2017) [2] tackled the issue of schema matching based on data instances in the relational database. He has proposed an efficient schema matching approach to identify the correspondences between attributes by fully exploiting the instances for numeric, alphabetic and mix data types. The proposed approach employs the concept of pattern recognition to create regular expression based on instances in order to identify attributes matches for numeric and mix data types. Besides, for the alphabetic data type, the approach involves

Google similarity to compute the semantic similarity score to capture the semantic relationships between instances. Table 3 summarizes the neural network approaches for instance based schema matching presented throughout this section.

TABLE III. SUMMARY OF THE MACHINE LEARNING APPROACHES

Author & Year of Publication	**Accuracy**	**Handling Instances**	**Matching Process**	**Technique**	**Matching-based Approach**
A. Doan et al., (2001)	Accuracy 71% - 92%.	String and Numeric	Auto	LSD	Semantic
J. Berlin and A. Motro, (2002)	Soundness = 0.81 Completeness = 0.81	String and Numeric	Auto	Bayesian learner and classifier	Semantic
F. Ji et al., (2009)	P=85% (Numeric) P=66% (String)	String and Numeric	Auto	Random Forest (RF) based Decision Tree	Syntactic
M. A. Osama et al., (2017)	P= 96%, R= 93%, F= 95%	String Numeric and Mixed	Auto	Similarity Metrics	Syntactic & Semantic

C. *Information Theoretic*

The third strategy that has been used to determine the matching between database schemas is information theoretic discrepancy. Most of the approaches applied this strategy employs the mutual information and distribution values to identify the correspondence between attributes [5], [10]. Mutual information indicates either the degree of dependency between attributes, or the information shared between any pair of attributes in the source schema to determine the relationship between the attributes of the target schema [5], [37]. It helps to reduce the uncertainty between known attributes and unknown attributes. Applying information theoretic discrepancy strategy is skillful and does not need prior knowledge about the constraints. Nevertheless, methods of information theoretic discrepancy need to analyze the probabilities of overlapping in the values being compared [2], [10].

Two approaches for schema matching based on information theoretic discrepancy are proposed by K. Jaewoo, and F. J. Naughton [38] and K. Jaewoo, and F. J. Naughton [39]. The idea of these two approaches is similar to the approach proposed by L. Yan [37]. However, these approaches are further extended to handle the problem of opaque data values beside the issue of opaque column names and schema information. The work in [39] handles the remaining unsolved challenge of the previous work. This includes improving the computational complexity process of the graph-matching problem. Giunchiglia et al. (2004) [40] address the issue of the semantic match between database schemas. They have proposed an information theoretic discrepancy based approach utilizes WordNet as a knowledge source to determine the semantic relations of two concepts instead of similarity coefficient with values between 0 and 1. L. Yan [37] introduced information theoretic discrepancy based approach that tackles the issue of schema matching between schema when the interpretations of schema information are incorrect or ambiguous. This is achieved by evaluating the instances in schemas, playing as equivalent role as schema information.

In addition, T. B. Dai et al. (2008) [19] suggested an instance schema matching approach based on information theoretic discrepancy to identify the correspondences between schemas. However, the work comprises a technique that finds semantic similarity instances between compared attributes in different tables. Lastly, the work introduced by J. Partyka, et al. [41] has also highlighted the issue of syntactic and semantic schema matching in the database. They have proposed information theoretic discrepancy based approach that aims at identifying the semantic as well as syntactic correspondences attribute via their instances sets. Table 4 summarizes the neural network approaches for instance based schema matching presented throughout this section.

TABLE IV. SUMMARY OF THE INFORMATION THEORETIC APPROACHES

Author & Year of Publication	**Accuracy**	**Handling Instances**	**Matching Process**	**Technique**	**Matching-based Approach**
K. Jaewoo, F. J. Naughton, (2003)	P = 75%, R=79%	String	Semi	Un-interpreted matching technique & Two-steps technique	Syntactic
F. Giunchiglia et al. (2004)	P=100%, R=90%, F=95%	String	Auto	Ontology-based	Semantic
L. Yan, (2008)	P = 70%	String	Auto	Domain-independent schema matching technique	Syntactic
T. B. Dai et al., (2008)	Integrability = 92%	String	Auto	N-gram	Syntactic
J. Partyka et al., (2009)	-	String and Numeric	Auto	N-gram & Google Similarity	Syntactic and Semantic

D. *Rule Based*

Last but not least, applying rule-based methods for schema matching between database schemas leads to various benefits. This encompasses the low cost of the matching process; it is not necessary to use training data and produce a quick and concise result in capturing valuable user knowledge about the domain.

C. H. E. Cecil, et al. [42] introduced rule-based approach exploits attribute identification to explore data instances that identify the correspondence between attributes. The correspondence between attributes can be detected and integrate together; in the worst case schema information might be insufficient or misleading. To achieve accurate matching between schemas, a set of rules has been described to classify schema attributes. However, the approach needs to identify the entity identification prior the match; therefore, the approach might fail to identify precise match if entity identification is not available. A. Bilke and F. Naumann [43] introduced a rule-based approach that benefits from the existence of duplicates in a data set to automatically identify matching attributes. The approach uses the rule "two attributes match if they have the same data values".

The work presented by B. Zapilko et al. [14] addressed the issue of instance based schema matching in the database. They have proposed a rule-based approach which utilizes a predefined regular expression to identify the matching patterns of instances. The idea of the proposed approach relies on employing the available statistical data to develop precise patterns and regular expressions that can be fully exposed for schema matching. Table 5 summarizes the neural network approaches for instance based schema matching presented throughout this section.

TABLE V. SUMMARY OF THE RULE BASED APPROACHES

Author & Year of Publication	Accuracy	Handling Instances	Matching Process	Technique	Matching-based Approach
C. H. E. Cecil, et al. (2003)	Matched attributes =72%	String, Numeric and Mixed	Auto	Attribute Identification Method	Syntactic
A. Bilke and F. Naumann (2005)	P=75%, R= 87%	String	Auto	Instance Similarity	Semantic
B. Zapilko et al., (2012)	-	Statistical Data	Auto	Regular Expression	Syntactic

VI. DISCUSSION AND RESEARCH WORK DIRECTIONS

From the work presented throughout this paper, it can be concluded that matching heterogeneous databases is considered as one of the biggest challenges of data integration in database applications. Many approaches relying on metadata schema information to solve the heterogeneities among different information sources such as classes and structure information [9], [11]. However, relying only on schema information is insufficient, and in many cases might be meaningless. Furthermore, it is not always necessary that metadata schema information is present and appropriate to be used in schema matching process [2]. Due to these issues, there have been various approaches of instance-based schema matching proposed to find the correspondences between schema attributes. Most of these previous approaches attempt to exploit the available instances by treating them as strings including instances with numeric values [5], [17], [18], [37], [43].

It can also be observed that shifting to instance matching may not be an easy task as it seems due to some difficulties relevant to its application and time constraints as well as other reasons. Numerous researchers highlighted some challenges regarding instance based schema matching usage or application. For example, even though, the instance matcher is more reliable and accurate, however, it is much slower and time consuming compared to the schema (metadata) matcher because it relies on the entire contents (instances) of the schema to be verified [2]. Moreover, the content of the database is updated more frequently compared with schemas in real-world databases.

In the following we set out the most interesting areas that should be discovered by researchers raising the issue of schema matching in database. In these subsection many research opportunities can be exploited by interested researchers in the database community.

A. Incomplete and Crowd-Sourcing Databases

An interesting area that should be explore is identify schema matching based on instances in a partially incomplete database. The incompleteness of the data contained in the database adds another crucial challenge for instance-based schema matching process. In some real-world databases such as web and crowdsourcing, there might be many attributes with missing values, outdated data, or duplicated data. Therefore, these incomplete and inaccurate data have a negative impact on the reliability of the matching results. Hence, many proposals argued that the results extracted from sampling include inaccurate, or incomplete data should not be trusted [44], [46]. This reflects the challenges of sampling selections for the instance level matching which requires more attention. Besides, in cowdsourcing database the work is done by human, thus, humans are much more expensive than the machine [45]. Hence, we suggest that further research needs to be conducted to investigate the impact of the incompleteness of the data on sample selection which ultimately influences the accuracy of the matching result. Several important metrics related to cowdsourcing should be taken into consideration when design schema marching approach. This include quality control, latency control and cost control [45].

B. Uncertain Databases

Another interesting area that should be explored is an instance-based schema matching in uncertain databases. In uncertain databases, the values are not discrete and vary in a range of values [45]. Data uncertainty might also have a negative impact on the matching process and the accuracy as well. Thus, it might not be possible to directly apply the conventional instance-based schema matching technique on uncertain databases as it might incur higher processing cost and compromising the match quality. We also urge to explore new matching techniques that best fit with uncertain databases ensuring high matching accuracy and shortest processing cost.

C. Big Data

Last but not the least, big data become a formidable research area and attract many researchers due to the rapid increase in the data volumes. A hot research area that should investigated in big data is schema matching in which there are tens or hundreds of millions of records and analyzing the sample might lead to an exhaustive process that consumes a significant amount of time. Hence, applying the traditional instance-based schema matching might be inadequate and impractical due to the large size of the database which results in longer processing time and more expensive cost [46]. Thus, it is important to continue investigating and attempt to develop techniques that work for data with high volumes.

VII. Conclusion

Schema matching is a challenging issue in many contemporary database applications, including data integration, data warehousing, E-commerce, and semantic query processing. Schema matching aims at discovering the correspondences between attributes of database schemas. This paper investigates the current problems related to schema matching process in database systems. Besides, we provide a comprehensive classification of schema matching approaches designed for instance-based schema matching. In particular, we distinguished between schema level and instance-level, element level, and structure level, and linguistics and constraint matchers, and discussed the combination of multiple matchers (hybrid and composite matcher).

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Lung-Deep: A Computerized Tool for Detection of Lung Nodule Patterns using Deep Learning Algorithms

Detection of Lung Nodules Patterns

Qaisar Abbas
College of Computer and Information Sciences,
Al Imam Mohammad Ibn Saud Islamic University (IMSIU),
Riyadh, Saudi Arabia

***Abstract*—The detection of lung-related disease for radiologists is a tedious and time-consuming task. For this reason, automatic computer-aided diagnosis (CADs) systems were developed by using digital CT scan images of lungs. The detection of lung nodule patterns is an important step for the automatic development of CAD system. Currently, the patterns of lung nodule are detected through domain-expert knowledge of image processing and accuracy is also not up-to-the-mark. Therefore, a computerized CADs tool is presented in this paper to identify six different patterns of lung nodules based on multi-layer deep learning (known as Lung-Deep) algorithms compare to state-of-the-art systems without using the technical image processing methods. A multilayer combination of the convolutional neural network (CNN), recurrent neural networks (RNNs) and softmax linear classifiers are integrated to develop the Lung-Deep without doing any pre- or post-processing steps. The Lung-Deep system is tested with manually draw radiologist contours on the 1200 images including 3250 nodules by using statistical measures. On this dataset, the higher sensitivity (SE) of 88%, specificity (SP) of 80% and 0.98 of the area under the receiver operating curve (AUC) of 0.98 are obtained compared to other systems. Hence, this proposed lung-deep system is outperformed by integrating different layers of deep learning algorithms to detect six patterns of nodules.**

Keywords*—Computer-aided diagnosis; lung nodules; patterns detection; deep learning; convolutional neural network; recurrent neural network

I. Introduction

Lung cancer is increasing rapidly as estimated in 2016 [1] throughout the world. If lung cancer is detected at an early stage then it will definitely be cured but the chances for survival rate is below or is less than 70%. The radiologists are extensively using a high-resolution computed tomography (HRCT) [2] digital imaging tool and computer-aided diagnosis (CAD) systems to detect and diagnosis lung cancer. However, if the clinical experts are only using HRCT scan images to diagnosis lung cancer then it is a time-consuming job [3] to detect small lung nodules. In addition to this, the size of lung nodules is varying widely from few millimeters to several centimeters. Even though, it is also difficult for radiologists to maintain the screening process during regular visits of patients.

To solve above-mentioned problems, the automatic computer-aided diagnosis (CADs) systems were developed to detect and differentiate among disease nodules from HRCT digital images. In recent years, automatic CAD systems [4]-[11] are developed to improve the diagnostic accuracy of clinical experts. All those CAD systems were trying to compensate the problem of manual interpretation of lung nodules and reduce false positive. In addition to this, the HRCT scan images are visually much cleared compared to other scanning techniques but still, it is hard to detect small pulmonary nodules [9]. Therefore, it is also difficult for the CAD systems to automatically detect them from the CT scan images as there are other objects also presented.

It noticed that many authors utilized complex image processing techniques to detect lung nodules and the classification accuracy is less than 80%. Instead of just detection of lung nodules, there is another step to classify those nodules into six different patterns such as honeycombing, ground glass, bronchovesicular, nodular, emphysema-like, and normal as required by the radiologists. However, the author did not find any CAD tool or study that classified six different patterns of lung nodules without using pre- or post-processing steps. It is very much important to classify them too perfectly for diagnosis of lung-related diseases instead of just differentiation between benign and malignant nodules. Hence, the main focus of this paper is to develop an effective system for classification of six lung nodules patterns from HRCT scan images through state-of-the-art deep learning systems by avoiding complex image processing techniques.

Although, there were CAD systems developed in the previous recent studies. Those CAD tools were described here to provide the background about the past studies. Especially in [10], the author’s utilized image processing and pattern recognition methods to differentiate between malignant and benign lung nodules instead of classifying lung nodule patterns after extracting various forms of features. The authors performed classification decision based on traditional machine learning algorithms such as genetic algorithm (GA) and support vector machine (SVM). On 1405 lung nodules, the authors reported an accuracy of 93.19 %. In that study, the authors focused only on recognition of benign and malignant nodules instead of identifying different patterns of the lung nodule.

The previous CAD systems [3]-[10] based on three main steps, such as segmentation of lungs or nodules, extraction of features and afterward, the selection of most prominent features. The last stage is to classify these discriminative features for recognition of lung disease patterns. In the past studies, these steps are well-addressed to search the most effective features for categorizing of lung nodules. Unluckily, many those CAD systems required pre- or post-processing steps and complicated image processing algorithms. Therefore, it is very hard for them to recognize all kinds of lung nodules for diagnosis of lung cancer. Instead of using old machine learning and image processing algorithms, there is the latest trend through deep learning methods. In practice, the deep learning algorithms are not prerequisite any domain expert knowledge to define and select features. These deep learning based CAD systems are explained in the subsequent paragraphs.

The authors recognized malignancy of lung nodules in [11] through a Multi-crop Convolutional Neural Network (MC-CNN) model to automatically extract nodules features without using time-consuming pre- or post-processing steps. The classification decision is performed through max-pooling technique on CNN features map. Whereas in [12], the features for lung nodules from CT scan images are automatically extracted and classified using deep learning algorithm on 1018 cases. The authors integrated a convolutional neural network (CNN), deep belief network (DBN), and stacked denoising AutoEncoder (SDAE) in that study. In that study, the authors compared the performance of proposed system with hand-crafted features by using a 10-fold cross-validation method and area under the receiver operating characteristic curve (AUC). Whereas in [13], lung nodules are classified through the development of Multi-view convolutional neural networks (MV-CNN).The authors achieved higher classification result to differentiate benign and malignant lung nodules. In [14], the authors used a different approach by combing the genetic algorithm with deep learning to classify lung nodules without computing the shape of nodules. The presented methodology was tested on LIDC-IDRI dataset and showed the best sensitivity of 94.66%, specificity of 95.14%, an accuracy of 94.78% and area under the AUC of 0.949.

In [15], the authors used three pairs of convolutional layers and two fully-connected layers from CNN model to differentiate between benign and malignant lung nodules from CT scan images. Similarly in [16], a CNN model was employed to automatically learn image features and detect pulmonary nodules from CT scan images. In contrast to these approaches, the authors used both hand-crafted features and deep learning features in [17]. For automatically defining the deep features, the authors used deep learning models of stacked denoising autoencoder (SDAE) and CNN. Whereas to define hand-crafted features, they utilized Haar-like and HoG features for detection of lung nodules in CT images. Same in [18], the authors used hand-crafted features combined with deep features to identify pulmonary nodules from CT scan images. They obtained higher accuracy compared to manual segmentation by radiologists.

The author did not find any study that classified six different patterns (honeycombing (HCmb), ground glass (GGlass), bronchovesicular (BCho), nodular (NDLR), emphysema-like (EmpMlk), and normal (NRM)) of lung nodules without pre- or post-processing steps. It is very much important to classify these lung patterns to perfectly identify lung-related diseases instead of just identifying benign and malignant lesions.

The basic purpose of this paper is to develop a computerized diagnostic system to detect lung nodules (Lung-Deep) based on advanced deep learning algorithms for early detection of lung cancer without extracting and selecting hand-crafted features. This paper demonstrates that patterns of lung nodules are classified without segmentation of nodules or defining hand-crafted features which are time-consuming tasks. The primarily main of this research study is to develop a system for classification of various patterns of lung nodules through integration of different layers of deep-learning algorithms compared to conventional machine learning algorithms. There are six lung disease tissues, such as honeycombing (HCmb), ground glass (GGlass), bronchovesicular (BCho), nodular (NDLR), emphysema-like (EmpMlk), and normal (NRM). In this study, six lung nodules patterns are classified by using a multilayer combination of convolutional neural network (CNN), recurrent neural networks (RNNs) and Softmax linear classifier algorithms [19]. Fig. 1 shows the example of six tissue patterns in the dataset during the follow-up operation.

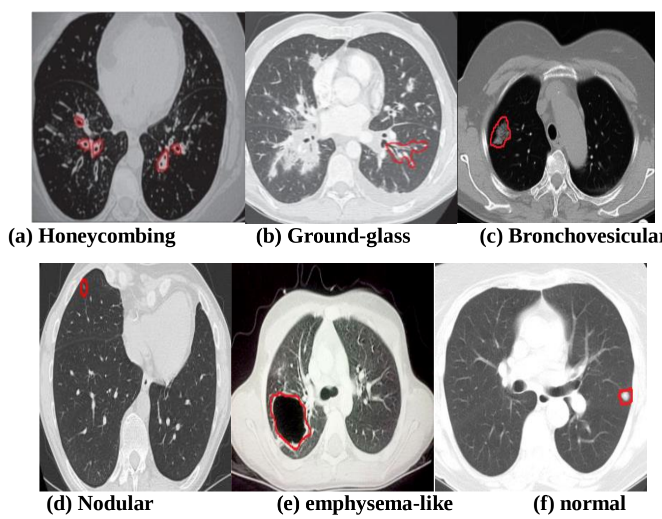

Fig. 1. An example of images taken from LIDC/IDRI dataset of classification of six lung disease pattern.

II. Methodology

A. Acquisition of Dataset

To test the proposed Lung-Deep system, a data set of CT scans was acquired from the Lung Imaging Database Consortium (LIDC) and Image Database Resource Initiative (IDRI) [20]. All those images in the LIDC datasets were contained different size of lung nodules. Therefore in this paper, this LIDC-IDRI dataset was utilized to test the performance of Lung-Deep system.

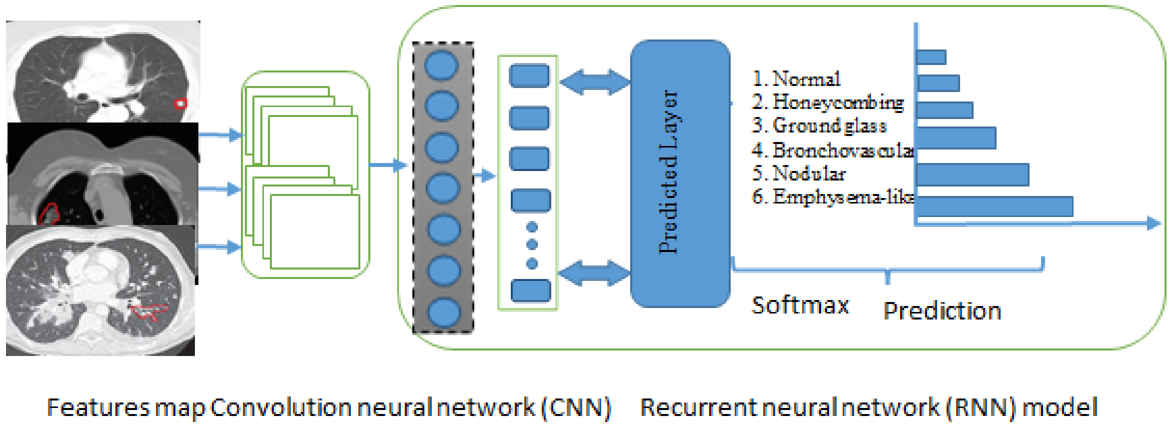

Fig. 2. A methodological systematic diagram of proposed lung-deep system for classification of six lung nodules patterns based on deep learning architecture.

From all these images, the 300 CT cases and 3,250 lung nodules are selected for evaluating the Lung-Deep system. From each scan images, the region-of-interest (ROI) of lung nodules are defined of size (200 x 200) pixels. Moreover, these 3,250 lung nodules are manually defined contours around lung nodules by an experienced radiologist. An example of manual segmentation of lung nodules from one CT scan image is visually shown in Fig. 1.

B. Proposed Method

A combination of the convolutional neural network (CNN) and recurrent neural networks (RNNs) deep learning algorithms are used in this paper to detect lung nodules from CT scan images. The CNN model [19] is used to transform input images into features representation into layers in an unsupervised fashion. In practice, the CNN model is the top variant of the deep learning algorithm is used when an image contains multiple objects. Therefore to extract features from lung nodules, the CNN model extracts the features and represented them using multiple features map. Afterward, a supervised RNN model is integrated to optimize the features extracted from CNN layer. Finally, the six lung nodules patterns are recognized through Softmax linear classifier.

The six lung nodules patterns are identified by using a powerful combination of CNN, RNN, and Softmax multi-layer deep learning algorithms. According to a literature review, it noticed that the CNN models are defined effective descriptive features set for recognition tasks instead of using hand-crafted features. In practice, the CNN model is to transform the low-level pixels to high-level one. However, the features define by CNN models are not optimized, so the recurrent neural networks (RNNs) model is integrated to perfectly optimize features.

In this paper, two-layers are utilized for un-trained CNN model to extract the features from extracted ROI lung nodule image of size (200 x 200) pixels. The first layer of CNN model contained 10 feature maps and the second one has 20 maps with a kernel size of 1 from each ROI lung nodule image. These two fully connected layers contain 4000 and 2000 nodes, respectively. The input to this CNN model is ROI lung nodule image of size (200 X 200) pixels. In order to optimize of features, the RNN model is applied with two-fully connected layers. In the past studies, the RNN model was outperformed to select most discriminative features that can provide better classification results. The RNN models are known as recurrent because they perform the same task for every feature of a sequence, with the output being depended on the previous computations. The RNN models are different in compared to feed forward neural network approach. In the feed forward neural network, the network is organized via layers and information flow unidirectional from input pixels to output. However, in RNN architecture, the flow of information is undirected cycles in the connectivity of like some patterns. This multilayer architecture RNNs model does not have to be arranged in terms of layers and directed cycles are also admissible. In practice, the neurons are actually allowed in this architecture to be fully-connected. In this paper, two-fully connected layers are utilized to optimize the features extracted by CNN model in the previous step. In the first layer, there are 1000 nodules. Whereas in the second layer, the RNN model has 500 nodes to represent the probabilities of six different lung nodule patterns. In this paper, the RNN model is used in an unsupervised manner. The architecture of RNNs model with CNN is shown in Fig. 2.

The Softmax linear classifier is used to six different patterns in a supervised fashion with already known class labels (Y). It is a statistical model that attempts to learn all of weight and bias parameters by using the learned features of the last hidden layer. In the case of binary classification (k=6), the softmax regression hypothesis outputs $h(x)$. The predictive is, therefore, a multinomial distribution, which can be naturally parameterized by a softmax function at the output layer. In general, the experiments in this paper aim to predict at the finest granularity found in the data, so as to maximize the generative flexibility of the network.

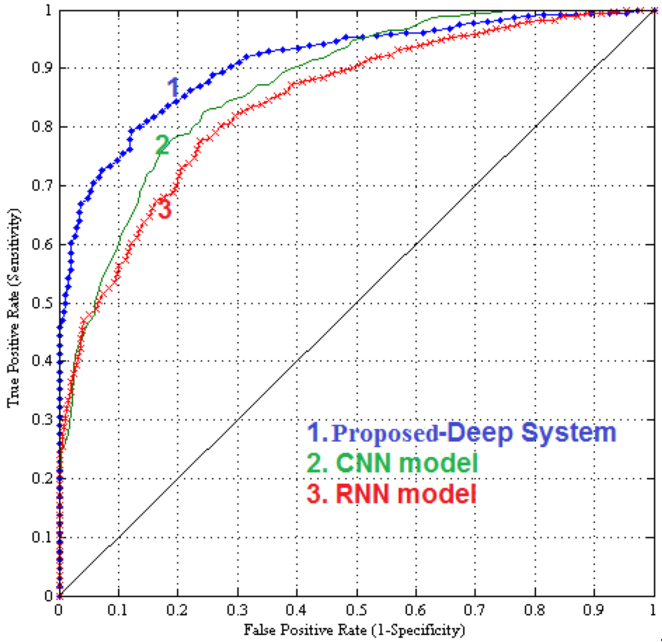

Fig. 3. Area under the receiver operating curve (AUC) of the proposed deep system compared to other deep learing systems on classification of six lung disease pattern.

III. Experimental Results

The performance of Lung-Deep system is evaluated and compared by using statistical measures such as sensitivity (SE), specificity (SP) and area under the receiver operating curve (AUC) [21]. For comparisons with ground truth, there are 3,250 lung nodules utilized, which are manually defined by an experienced radiologist. This lung nodules dataset is divided into 35% training and 65% testing examples and applied 10-fold cross-validation test for calculating the robustness of Lung-Deep system. In this training and testing of Lung-Deep, lung disease patterns are divided into 6 classes such as honeycombing (HCmb), ground glass (GGlass), bronchovesicular (BCho), nodular (NDLR), emphysema-like (EmpMlk), and normal (NRM). It noticed that the higher the value of AUC indicates that the system is going to achieve significant better classification results.

On a total of 3,250 lung nodules, the average statistical measures of the Lung-Deep system are displayed in Table 1. From this table, it observed that, on average, the best lung nodules detection results are obtained such as SE of 88%, SP of 80.0% and AUC of 0.89. In the case of Hcmb lung patterns, the SE of 87%, SP of 74.5% and AUC of 0.89 are obtained. In GGclass nodule patterns, the Lung-Deep system is obtained best results such as 90% of SE, 79.5% and AUC of 0.90. Whereas, in the case of BCho patterns, a SE of 85%, SP of 80% and AUC of 0.87 values are obtained. Compared to other lung nodules patterns, the statistical significant results are obtained by the proposed Lung-Deep system in case of Nodular (NDLR) lung nodules such as SE of 93%, SP of 82.5% and AUC of 0.92 values. As a result, the proposed Lung-Deep system improved the detection accuracy of lung nodules. It happens due to combining of the convolutional neural network (CNN), recurrent neural network (RNN) and softmax deep classifiers for detection of lung disease patterns.

In this paper, a computerized system is developed to automatically classify disease patterns into six categories by using HRCT scan images. For early detection of lung cancer, the radiologists are facing many difficulties to interpret a large number of CT scan images. In such a consequence, if automatic CAD system may improve lung cancer detection rate and reduce errors to classify lung nodules. The proposed Lung-Deep system is implemented to use the features set generated by a convolutional neural network (CNN) and optimize using recurrent neural network (RNN), model. These features are finally classified candidate lung nodules as honeycombing (HCmb), ground glass (GGlass), bronchovesicular (BCho), nodular (NDLR), emphysema-like (EmpMlk), and normal (NRM). The performance of Lung-Deep system shows an improvement as used large data set. For the 32,50 lung nodules in this dataset, the Lung-Deep approach outperforms by recognizing and categorizing less than 11% of the observed false negatives. Therefore, it concludes that the presented system is expected to perform with high accuracy given the availability of large data set. Moreover, this technique by using deep learning algorithms do not require any pre- or post- processing steps or domain expert knowledge for selection of features.

The comparisons with other state-of-the-art deep learning systems are also performed in this study to show the importance of integration of various layers for the development of Lung-Deep system using AUC curve. These comparisons results are displayed in Fig. 3. The obtained results indicate that an effective computerized system is developed in this paper to detect six lung nodules by using a powerful combination of CNN, RNN, and Softmax multi-layer deep learning algorithms. According to the literature review, it noticed that the CNN models are defined effective descriptive features set for recognition tasks instead of using hand-crafted features.

TABLE I. The Detection of Lung Nodules Disease Patterns Based on Proposed Lung-Deep System on Total 32, 50 Nodules

No.1	*Nodule Patterns*	*SE* [a]	*SP* [b]	*AUC* [c]
1.	Honeycombing (HCmb)	87%	74.5%	0.89
2.	Ground glass (GGlass)	90%	79.5%	0.90
3.	Bronchovascular (BCho)	85%	80.0%	0.87
4.	Nodular (NDLR)	93%	82.5%	0.92
5.	Emphysemalike (EmpMlk)	83%	76.5%	0.85
6.	Normal (NRM)	90%	84%	0.89
Average Results		**88%**	**80%**	**0.89**

[a.] Sensitivity, [b.] Specificity, [c.] Area under ROC curve

IV. Conclusions

A new computerized lung-nodules pattern detection system using multilayer deep learning algorithms is developed in this paper for the early diagnosis of lung cancer or lung-related disease. The proposed Lung-deep system is better than state-of-the-art systems due to use of latest machine learning techniques without using complex image processing algorithms. A dataset of 3250 lung nodules are utilized in this study to test the performance of proposed Lung-Deep system.

Worldwide, the early detection of lung cancer improves the patient survival rate and therefore in this study, an improved computerized system is proposed to classify lung nodules without clinical experts. Accordingly, the major contribution of this development lies in the application and analysis of two variants of deep learning architectures for classification of six lung nodules disease patterns. The developed system was tested and evaluated on the LIDC/IDRI database and the best result was achieved. For detection of six different patterns on LIDC/IDRI dataset, a good performance is obtained in terms of sensitivity, specificity, and area under ROC curve about 88%, 80%, and 89%, respectively. It outperforming the results obtained by using of variants of deep learning techniques. It is important to classify lung nodules into benign and malignant based on disease patterns that will be focused in the future work. In addition to this, the segmentation of lung nodules will be automatically performed [22] compared to the use of manual segmentation in this study done by an expert radiologist. Hence, the development of this CAD tool for pattern classification is having a great clinical importance and it assists radiologists to better identify the lung-related disease.

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Breast Cancer Detection with Mammogram Segmentation: A Qualitative Study

Samir M. Badawy[1]
Industrial Electronics and Control Eng. Dept,
Faculty of Electronic Engineering, Menoufia University,
Egypt
[1]drsamirb@gmail.com

Alaa A. Hefnawy[2], Hassan E. Zidan[3], and
Mohammed T. GadAllah[4]
Computers and Systems Department,
Electronics Research Institute (ERI),
Egypt
[2]alaa@eri.sci.eg, [3]hbanna@eri.sci.eg, and
[4]Mohammed.tag.1986@eri.sci.eg

***Abstract*—Mammography is specialized medical imaging for scanning the breasts. A mammography exam (A Mammogram) helps in the early detection and diagnosis of breast cancer. Mammogram image segmentation is useful in detecting the breast cancer regions, hence, better diagnosis. In this paper, we applied enhanced double thresholding-based approach for Mammograms' image segmentation. Moreover, we added the borders of the final segmented image as a contour to the original image helping physicians to easily detect the breast cancer into different Mammograms. The result is enhanced wise effect onto breast cancer qualitative detection into Mammograms, helping physicians for better diagnosis. Generalization for our study is possible for not only x-ray based Mammograms, but also for all biomedical images, as an enhanced segmentation way for better visualization, detection, and feature extraction, thus better diagnosis. Moreover, this manual thresholding method has the advantage of not only reducing processing time but also the processing storage area.**

Keywords—Image processing; double thresholding segmentation; breast cancer detection into mammograms

I. Introduction

Breast cancer is the second common cancer worldwide after the lung cancer, the fifth common cause of cancer death, and the major cause of cancer death in women [1]. Breast cancer is the second common cancer in women after skin cancer in the U.S. Both men and women can have a breast cancer, but there are about 100 times more new cases of breast cancer in women than in men every year [2].

Beginning in the 1980s, screening mammography led to sweeping improvements in early detection of breast cancer [3]. Mammography is a specialized medical imaging that uses a low-dose x-ray system for scanning the breasts. A mammography exam, called mammogram, helps in the early detection and diagnosis of the breast diseases in women [4].

Screening mammograms are administered to detect breast cancer in women who have no apparent symptoms. Diagnostic mammograms are used after suspicious results on a screening mammogram or after some signs of breast cancer guide the physician to check the tissue [5]. Image segmentation is an effective way for detecting the breast cancer regions in mammograms, hence, better diagnosis. Segmentation refers to the operation of partitioning an image into component parts, or into separate objects, and there is more than one approach for image segmentation [6]. More trials had been concerned with breast cancer detection by different segmentation approaches [7]–[11]. Double thresholding segmentation approach is a simple and basic way for dealing with cancer cells image segmentation [12].

In this paper the same technique of double thresholding segmentation applied in [13] and [14] for Mammograms' image segmentation was implemented. An enhancement has been done to the segmentation approach by applying some morphological operations after double thresholding. As a post-processing the borders of the final segmented image as a contour was added to the original mammogram image helping physicians to better diagnose the breast cancer in mammograms. The proposed approach has been applied on more than one mammogram scans taken from [15].

The result is an enhanced detection and a better visualization of the breast cancer in different mammograms. Finally, it is concluded that enhanced double thresholding segmentation applied has improved wise effect onto the breast cancer detection into mammograms, helping physicians for better diagnosis. The paper is organized as follows: In Section 2, we display the materials and methods had been used in our paper including the enhanced segmentation approach, been applied on a four different Mammograms. A brief discussion of our results is displayed in Section 3. Finally, some concluding remarks are given in Section 4.

II. Materials and Methods

A four sample Mammogram images had been used in our study, every image is 1024 pixels by 1024 pixels; taken from the MiniMammographic Database [15]. The top row of Fig. 3 illustrates the four sample images included in our study in the same order presented in Table 1.

A. Double Thresholding Segmentation

Thresholding is a vital part of image segmentation, where it is required to isolate the objects from the background. Here, in this paper we used the same way of double thresholding segmentation applied in [13] and [14] for mammograms' image segmentation.

Double Thresholding Segmentation can be illustrated simply by choosing two pixel values **L** and **U** from our image, *where* **L** is the lower limit of thresholding and **U** is the upper limit of thresholding, and apply the thresholding operation as: *A pixel becomes white if its grey level is between **L** and **U**, and black if its grey level is otherwise* [6].The result is a binary (black and white) image, white for all pixels' grey levels lies in-between the two limits value **L, U**, and black for all the others. For every image we work on we have to determine almost the pixel values for the area we need to put the scope on, and select a better thresholding limits for better extracting for the needed regions. For the four sample mammograms included in our study, after many trials we choose L = **0.75**& U = **0.96**.

The result of the double thresholding operation is illustrated in the second row of Fig. 3.*MatLab_R2017a* had been used in our study for implementing the double thresholding segmentation and the following processing including some morphological operations.

B. Masking and Morphological Operations

A specified mask had been made especially to remove the unwanted borders into the mammogram image after double thresholding (see Fig. 1).

The proposed mask is 1024 pixels by 1024 pixels. It had been designed accurately to be suitable for almost all Mammographic Image Analysis Society (MIAS)'s MiniMammographic database because the size of all its images is 1024 pixels by 1024 pixels.

Moreover, all MIAS's database images had been centered in the matrix, so the mask is suitable for both; Mammograms with right position of the breast apex and Mammograms with left position of the breast apex.

After masking, some morphological operation had been done for smoothing borders and filling holes; including: morphological opening (erosion followed by dilation), dilation, thinning, and finally filling holes. The results of the four sample images after Masking and Morphological operations are shown in the third row in Fig. 3.

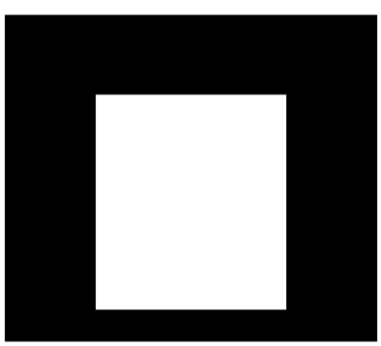

Fig. 1. The applied Mask after double thresholding.

C. The Applied Segmentation Approach

The Applied segmentation approach can be summarized into the flowchart shown in Fig. 2.

Step1: The original image is segmented by double thresholding producing the second row into Fig. 3.

Step2: The result of Step1; is multiplied by the mask shown in Fig. 1, *after that;* supposed to some morphological operations producing the third row into Fig. 3.

Step3: Contouring the abnormalities areas onto the original image by the boundaries of the resulted binary image from Step2; producing the Final Enhanced Segmented Mammogram shown in the last row of Fig. 3.

III. Results and Discussion

Final results of the four sample mammogram images are shown in Fig. 3; where, ***the top row*** represent the original mammogram images ordered from 1 till 4 in the same order of the four Mammogram images presented into Table 1. ***The second row*** is the result of applying the double thresholding segmentation explained in Section2 in this paper. ***The third row*** is the result after masking and processing. ***The bottom row:*** final contoured images.

The final contoured images assure the wise of the applied approach into highlighting the abnormalities areas helping the physicians to easily detect the breast cancer into Mammograms. The applied enhanced double thresholding segmentation approach can be useful not only in the breast cancer detection into Mammogram scan images, but also, in extracting the regions of interest from biomedical images by selecting the appropriate threshold limit, hence helping the physicians for better diagnosis. So the generalization of our study is already possible for all biomedical images, as an enhanced segmentation way for better visualization, detection, and feature extraction, thus better diagnosis. Moreover, this manual thresholding method has the advantage of not only reducing processing time but also the processing storage area.

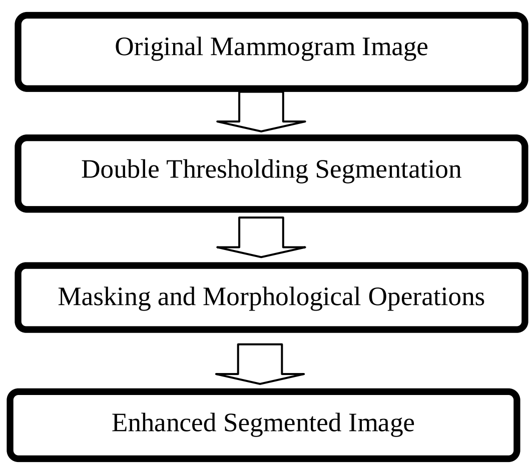

Fig. 2. Flowchart of the applied segmentation approach.

TABLE I. DESCRIPTION OF THE FOUR SAMPLES MAMMOGRAMS BEEN USED IN OUR STUDY

	Character of background tissue	**Class of abnormality present**	**Severity of abnormality**
Image 1	Fatty-glandular	Asymmetry	Malignant
Image 2	Fatty	Other, ill-defined masses	Malignant
Image 3	Dense-glandular	Architectural distortion	Malignant
Image 4	Fatty-glandular	Well-defined/circumscribed masses	Malignant

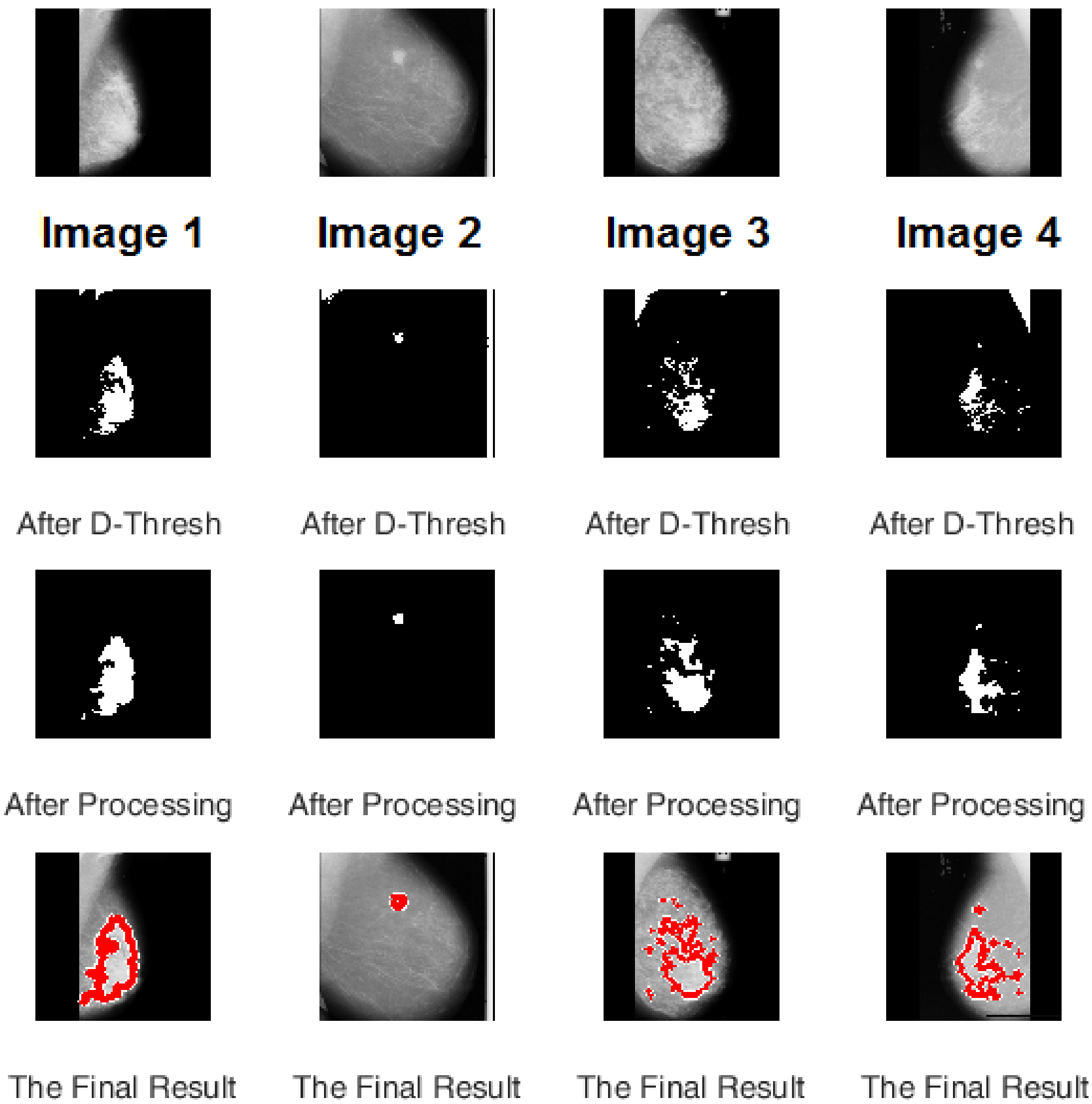

Fig. 3. Final Results of the four sample Mammogram images; *top row:* the original mammogram images, *second row:* after double thresholding, *third row:* after masking and processing, *bottom row:* final contoured images.

IV. Conclusion

In our study we proved that enhanced double thresholding segmentation applied has enhanced wise effect for breast cancer qualitative detection into Mammogram scan images, helping physicians for better diagnosis. Generalization for our study is already possible for not only x-ray based Mammograms, but also for all biomedical images, as an enhanced segmentation way for better visualization, qualitative detection, thus better diagnosis. Moreover, this manual thresholding method has the advantage of not only reducing processing time but also the processing storage area.

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Cloud Computing: Empirical Studies in Higher Education

A Literature Review

Abusfian Elgelany
Faculty of Computer Studies & Information Technology
Garden City University
Khartoum - Sudan

Weam Gaoud Alghabban
Computer Science Department
Dhiba University College, University of Tabuk
Saudi Arabia

***Abstract*—The advent of cloud computing (CC) in recent years has attracted substantial interest from various institutions, especially higher education institutions, which wish to consider the advantages of its features. Many universities have migrated from traditional forms of teaching to electronic learning services, and they rely upon information and communication technology services. The usage of CC in educational environments provides many benefits, such as low-cost services for academics and students. The expanded use of CC comes with significant adoption challenges. Understanding the position of higher education institutions with respect to CC adoption is an essential research area. This paper investigated the current state of CC adoption in the higher education sector in order to enrich the research in this area of interest. Existing limitations and knowledge gaps in current empirical studies are identified. Moreover, suggested areas for further researches will be highlighted for the benefit of other researchers who are interesting in this topic. These researches encourage institutions of education especially in higher education to adopted cloud computing technology.**

Keywords—Cloud computing; education system; e-learning; information and communication technology (ICT)

I. Introduction

Education plays a prime role in society's life. One of the most promising paradigms for education is electronic learning (e-learning). E-learning can be defined as "All forms of electronically supported learning and teaching, which are procedural in character and aim to affect the construction of knowledge with reference to individual experience, practice, and knowledge of the learner. Information and communication systems, whether networked or not, serve as specific media (specific in the sense elaborated previously) to implement the learning process" [1]. In recent decades, there has been substantial interest in e-learning from many people in the field of educational, especially from those in the higher education sector [2]. Higher education institutions (HEIs) play a considerable role in the development of societies. With the evolution of technology, many universities have migrated from traditional forms of teaching to online "e-learning" services, and they rely upon information and communication technology (ICT) services to do so. To support e-learning, these educational institutions must have an adequate IT infrastructure and massive investment, which is difficult to acquire in times of profound recession. In fact, some universities already face difficulties in providing different IT services for their academics and students [3].

Currently, cloud computing (CC) technology has an attractive proposition for educational environments [4], as shown in Fig. 1 [5], and it presents a promising solution to the challenges associated with reducing IT costs [6]. Currently, the use of cloud-based applications is increasing among HEIs [4]. One recent study of CC reported that in 2012, 43% of HEIs have implemented CC technology [7]. This percentage represents a 10% increase from 2011 poll data, and it is expected to continue rising over the next few years.

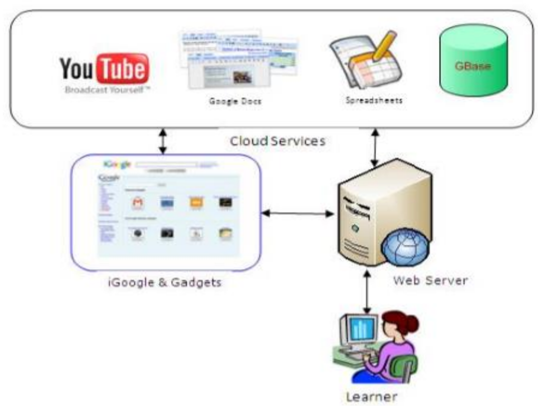

Fig. 1. Cloud-based e-learning system [5].

Today's students access the Internet constantly, and they explore the world through the Internet [6]. By accessing different programs, such as Twitter, Facebook, and Gmail, these students already are consumers of CC technologies [8]. Accordingly, [9] it has been demonstrated that CC solutions have become very attractive in supporting collaborative learning and have been incorporated in social theories of education, especially in higher education. As a result, HEIs administrators, either globally or locally, are asking IT staff to implement CC strategies, thus driving the trend of the higher education sector's increased adoption of CC [6]. Some benefits of CC for HEIs over traditional technologies are mobility, efficiency [6], economics, enhanced availability [10], increased productivity, scalability, and penetration of knowledge all over the world [11]. Moreover, common goals for CC include developing IT infrastructure in HEIs and increasing the access of university staff and students to a wider range of learning resources [12].

Therefore, the researchers are motivated to investigate the current state of the art of CC adoption in the higher education sector. The key contribution of this paper is identifying and exploring the current existing limitations and challenges identified in current empirical studies to enrich the research in this hot topic; this paper also aims to suggest areas for further investigation. This research can better inform other researchers who are interested in CC implementation in the field of higher education. Additionally, the gaps in the existing body of knowledge are highlighted. These gaps suggest essential areas of focus for future research on CC adoption in higher education.

The paper is organized as follows. Section II presents an overview about CC. Section III presents the research methodology. Section IV reports and discusses the results in depth. Section V presents conclusions from the review.

II. Cloud Computing

Over the last half century, CC has rapidly emerged as new computing technology, which evolved as a result of the advances in ICT [13], [14]. The term “cloud” was inspired from the “cloud” symbol that is typically used to symbolize the Internet in computer network diagrams [15].

Currently, it is hard to define CC, as there are many debates by researchers about the standard definition for it. While the discussions for the final definition continue to evolve, there are some characteristics of CC seem to be common to the most of its definitions in the literature. The National Institute of Standards and Technology (NIST) defines CC as “a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction” [16]. In [17], CC is referred to as a new operation rather than a new technology. Moreover, CC is defined as a convergence of utility computing, grid computing, and Software as a Service (SaaS) [18].

A. Cloud Service Models

Based on [19], CC model is composed of three main service models, as shown below in Fig. 2, which are Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS). The SaaS model of CC allows the user to use and access the software through the Internet for a low price, almost free. Thus, the CC allows the user to use specific applications without needing to install and run the application on the user's machine [19].

PaaS model of CC provides the consumer the development environment of a computing platform for building, testing, deploying and delivering applications or any other services through the cloud [20]. The IaaS cloud technology model provides the customers the required resources as a service from the cloud. These resources include processing, networks, storage and other computing resources that allow clients to deploy and run the software. Hence, the clients do not need to purchase the required resources; they only need to pay for the duration for which they use the provided services [21].

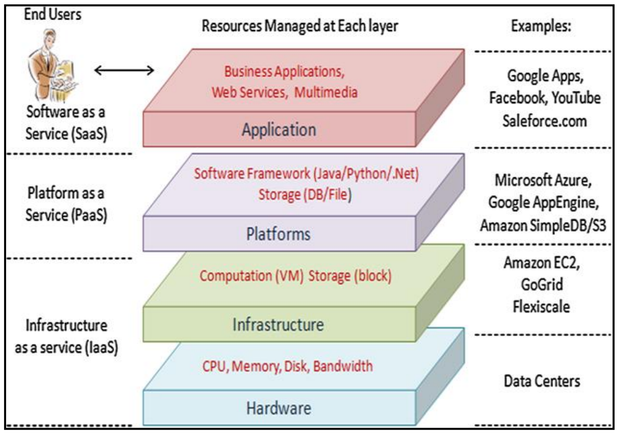

Fig. 2. Cloud computing services [20].

B. Cloud Computing Technology for Education

The advantages that CC technology can provide to academics and students make it an attractive option in higher education. One advantage to the users of CC of is the availability and ease of access using their mobile devices, university equipment, or any combination of these options at anytime and anywhere they find most beneficial. Another distinct advantage is the ability to share, process, edit, and store huge amount of data within educational environments.

One of the key characteristics of CC is an economy of scale [22]. This feature implies that cloud services can be delivered at a lower cost compared to in-house networks and computer infrastructure that is provided by educational institutions. Additionally, applying IT tools could allow access to resources globally, resulting in an increased learning quality [22]. Moreover, the use of CC could reduce the cost of resources and make education sustainability easy.

Currently, according to [23], education needs a new generation of academic staff, and students are different from their ancestors. As a result, students prefer the increased usage of new technology and applications. The CC application can benefit the students by enabling them with quick connections with each other and to the core of educational materials. CC provides the HEIs with the following benefits: 1) facilitate interactive learning; 2) the availability of huge amount of processing power; 3) no need for backup; and 4) provide a digital education environment and web-based services for academic staff and students [4]. For these valuable features, currently, all universities are transitioning to cloud-based applications.

III. Research Methodology

The search process includes reviewing various publications in some leading digital libraries such as IEEE Xplore, ScienceDirect, and SpringerLink published between 2014 and 2017. The researchers chose these years to determine the existing gaps in adopting CC in the higher education field. The researchers include empirical studies that discussed CC in higher education. The basic focus is to identify whether HEIs have adopted CC in their education management and systems.

A. Education System based on Cloud Computing

Education is fundamental to the nation's evolution and is vital to making dreams come true. The advent of CC in recent years has instigated interest from different educational institutions due to its features [24]. This technology brings a completely transformed learning experience to educational institutions [25] and it is used for cost effective and more efficient computing by centralizing storage, memory, computing capacity of personal computers and servers [2]. Moreover, CC provides a rich learning environment, a global collaboration among academics and students, and allows shared learning [25]. Additionally, CC applications provide flexibility for HEIs [2]. With the tremendous advantages of CC, this technology is expected to revolutionize the field of education, especially the higher education sector.

CC has a considerable status in the HEIs globally and locally. According to Katz et al. 2009 [26], 70% of HEIs in North America has moved to the cloud, and 50% have adopted CC collaborative system to enhance information sharing within the campus. Nearly all HEIs in the West region, according to [27], have a basic interest in adopting CC, at least at the departmental level. For example, according to Alshwaier 2012 [2], the University of California at Berkeley was focused on deploying SaaS applications in one of its courses. Moreover, the Medical College of Wisconsin Biotechnology and Bioengineering Center in the United States found that the usage of CC is very beneficial and provides them with a huge computational power by renting Google's cloud servers [28]. Moreover, some HEIs have adopted CC for economic reasons. For instance, Washington State University has suffered from budget cuts. However, the usage of CC has enabled the school to expand the educational services [15].

In Saudi Arabia, the IT market is considered as the largest market in the Gulf region [3]. The Saudi government has allocated a huge fund to improve the educational environment with the best technological facilities. However, there are new start-up universities in Saudi Arabia that lack e-learning tools compared to the older universities in SA [3]. Saudi universities still slowly seek to adopt CC in the higher education environment for distance learning and e-learning, while CC has been widely used in universities in different countries to deliver higher quality services to higher education [29]. Therefore, it is important to be aware of adopting CC in SA universities.

B. State of the Art

Related research covered the using of CC in higher education system over the last years are critically investigated. The usage of cloud services enables private and public educational institutions that work under financial constraints to update with the latest IT services and tools.

Migration to the cloud services refers to the process of moving data, applications, networks, and servers from in-premises to the cloud centers. However, the migration process still imposes a different range of challenges.

Alharthi et al. (2017) reported these issues, which are legal policies, security, and implementation. The researchers presented a framework for successful migration to the cloud environment in Saudi universities and identified a set of critical success factors concerned with the migration process. The results showed that majority of these factors were statistically significant except the physical location factor. The proposed framework can support the decision-making process about whether to migrate or not and can provide valuable data on cloud computing projects. Although the proposed framework was the first step to investigate the factors enabling the migration process, it had not been implemented in reality [3].

Another new e-learning framework based on private cloud and virtual private network was proposed by Jayasena and Song (2017). The proposed framework helps students in the university environment to access e-learning environment for resource sharing with less cost. The framework is scalable and increases availability and reliability, but it has limited access within campus networks only [30].

Ashtari and Eydgahi (2017) addressed the influence of individual users' perception towards the cloud computing applications. The researchers presented a framework focused on the association between a set of variables (IT self-efficacy, perceived cloud ease of use, computer anxiety, and users' perception of the usefulness and effectiveness of cloud computing applications) that have an influence on the cloud computing technology's perceptions for students at a university in Southeast Michigan. Additionally, the Technology Acceptance Model (TAM) model was used for analyzing adoption of cloud computing by students'. Although the usage of the TAM remains significant in technology evaluation after its adoption, there is a lack of any practical values and limited explanatory [4].

Arpaci (2017) also used the TAM for investigating the antecedents and consequences of CC adoption in higher education to achieve knowledge management. A questionnaire was distributed among undergraduate students in a Turkish university and analyzed by using structural equation modeling. The findings showed that the educational institutions promote CC adoption by increasing the awareness of knowledge management. Although the efficiency of this study, limited explanatory was one issue [31].

Rahimah and Aziati (2017) studied the factors that affect the CC implementation in HEIs focusing on SaaS. The researchers proposed a framework extracted from the Technology, Organization, and Environment (TOE) framework and integrated with the Diffusion of Innovation (DOI) theory for this study. Although the proposed framework accelerates the implementation process of computing technology, it does not consider the individual's resources or social support to adopt the new behavior [32].

Research conducted by Al-Hamami and Hashem (2016) looked into developing an efficient framework for Higher Education Ministry that serving all the universities in Iraq. The proposed framework provides some characteristics such as low cost, flexibility, mobility, and business continuity. However, there are some issues that need further investigations: security, reliability, and loss of sensitive data. Furthermore, there is a lack of standards to enable multiple clouds to work as a single entity [33].

Madhav and Joseph (2016) discussed how cloud computing could help higher education institutions in South Africa by providing a framework for the cloud-based virtual computing labs. Findings depicted by Madhav and Joseph (2016) revealed the cost saving on hardware and software and the flexibility of the cloud-based virtual computing labs. However, the usage of the proposed framework was limited to the campus [34].

Khan (2015) proposed a hybrid-computing model that facilitates the higher educational institutions in Saudi Arabia to share knowledge and different research activities. The proposed model improves the effectiveness and quality of teaching by providing support regarding course material, assessments, and projects. Additionally, it saves the budgets of institutions to update with the latest IT and provides a treasure of knowledge at one place. On the security aspect, however, Khan did not consider security issues in his proposed model [35].

A survey conducted by Alajmi and Sadiq (2016) demonstrate that cloud computing continues to play an increasingly significant role in higher education in the modern world. Higher education is embracing cloud-computing services due to economic advantages, increase productivity, and improve learning strategies and knowledge penetration. However, there is a debate on different issues such as privacy, integrity, and ownership of data. Moreover, there is a lack of new security techniques to adopt cloud computing in the universities [11].

Militaru et al. (2016) explored the factors that lead to cloud computing adoption in higher education based on the TAM framework by surveying 96 students at a university in Romania. Findings revealed that the factors are significant to enhance the understanding of cloud computing adoption for faculty members and students. However, there is a lack of any practical value and limited explanatory [36].

Another exploratory study based on Technology Organization Environment (TOE) framework conducted by Tashkandi and Al-Jabri (2015) aimed to identify the factors that affect cloud computing adoption by higher education institutions in Saudi Arabia. The factors were tested through statistical analysis, and the results revealed the significance of the following factors: complexity, relative advantage, and data concerns. Although the researchers provided a better understanding of factors affecting cloud computing adoption, they did not include bandwidth and reliability factors in their study [37].

Different studies in higher education demonstrate the usage of computational environments improve the learning process [8], and this encouraged Segrelles and Molto (2016) to introduce virtualized computing environments based on cloud computing using the On-demand Deployment of Infrastructures to Support Educational Activities (ODISEA) platform. The benefits have been evaluated at a university in Spain. Findings demonstrated that ODISEA provides students with highly ubiquitous access and strong economic benefits for higher education institutions. Although the platform has a lot of flexibility, it does have challenges due to the complexity of communication among its levels [38].

A case study conducted by Musungwini et al. (2016) explored the benefits of using Google Docs in academics and analyzed the factors affecting cloud computing adoption at a university in Zimbabwe. Interviews and questionnaires were conducted in order to get in-depth insight into the issues affecting the adoption of cloud computing. Findings revealed there are many benefits of Google Docs to academics, but there is also a lack of knowledge about how to use cloud computing among lecturers. There was a need to conduct different workshops for all lecturers to explain cloud computing. Although the researchers used different research design approaches, there was a lack of consideration for security issues [39].

Ibrahim et al. (2015) conducted a survey to analyze the evidence of cloud computing adoption in the educational sector. A total of 27 papers were included in the literature review. The results of the study revealed a clear lack of research focusing on using cloud computing in educational institutions [40].

Higher education institutions are facing challenges in providing IT support for educational activities. Hence, higher education institutions must consider opportunities afforded by cloud computing. For that, Pardeshi (2014) proposed cloud-computing architecture for higher education institutes that contains cloud computing deployment models, services models, and user domains. Additionally, a strategy for migration from the traditional system to cloud computing was presented. Although the proposed architecture improves agility and increases efficiency, it has not yet been evaluated [6].

The most common cloud computing service model that has an impact on the learning sector is Software as a Service (SaaS). Hence, Akande and Belle (2014) explored whether SaaS is a viable option for higher education institutions in South Africa. Interviews were conducted with undergraduate students regarding using Office 365 as SaaS. Findings revealed many advantages of using Office 365, such as installation, upgrading, and maintenance of applications. Additionally, Office 365 assists higher education institutions via cost reduction and improved access to resources. However, there are other solutions available rather than Office 365 that provide all the same features but with lower costs [12].

Based on the preceding extensive analysis, which focused on a critical review of the literature, the findings from previous studies are summarized below in Table 1.

TABLE I. SUMMARY OF RELATED STUDIES

Author(s)	Technology	Pros	Cons
Alharthi et al. (2017).	Framework	• Investigate the factors enabling the migration process to cloud in South Africa. • Supports decision-making processes whether to migrate or not. • Provides valuable empirical data for hiring cloud-computing projects.	• Not implemented.
Jayasena and Song (2017).	Framework	• Scalability. • Increases availability and reliability.	• Limited access within the campus.
Ashtari and Eydgahi (2017).	Framework	• Effective usage of the model.	• Lack of any practical values. • Limited explanatory.
Arpaci (2017).	Model	• Efficacy.	• Limited explanatory.
Rahimah and Aziati (2017)	Framework	• Accelerated technology implementation in HE.	• Does not consider the individual's resources or social support.
Al-Hamami and Hashem (2016).	Framework	• Lower cost. • Flexibility. • Mobility. • Business continuity.	• Security issues not considered. • Reliability issues. • Loss of sensitive data. • Lack of standards to enable multiple clouds to work as a single entity.
Madhav and Joseph (2016).	Framework	• Cost saving in HW and SW. • Flexibility.	• Only uses the framework within the campus.
Khan (2015).	Model	• Treasure of knowledge at one place. • Improves effectiveness and quality of teaching. • Budget saving.	• Security issues not considered.
Alajmi and Sadiq (2016).	Survey	• Increases productivity. • Penetration of knowledge. • Improves educational strategies.	• Integrity, privacy, security, and ownership of the data. • Lack of new security techniques.
Militaru et al. (2016).	Framework	• Effective framework.	• Lack of any practical values. • Limited explanatory.
Tashkandi and Al-Jabri (2015).	Framework	• Provides valuable insights about critical factors that affect adoption of cloud computing.	• Lack of including bandwidth and reliability.
Segrelles and Molto (2016).	Platform	• Flexible platform.	• The complexity of communication among the levels.
Musungwini et al. (2016).	Case study	• Using different research design approaches. • Better collaboration.	• Lack of considering security issue.
Ibrahim et al. (2015).	Survey	• High quality selected research.	------
Pardeshi (2014).	Architecture	• Improves agility. • Increases efficiency.	• Lack in the evaluation stage.
Akande and Belle (2014).	Model	• Allow focusing on teaching and learning. • Reduces cost. • Improves access to resources.	• Using costly application.

IV. RESULTS AND DISCUSSION

Although CC is gaining momentum in HEIs, many issues still need to be addressed. Based on the critical, in-depth analysis of collected previous empirical studies, many knowledge gaps are evident. Theses gaps present new limitations and challenges that need further investigation. The following list presents the issues that are the most pressing and are opportunities for further study:

- Most of the existing systems fail to consider reliability, security, privacy and integrity issues. Additionally, some systems have limited access only within the campus and fail to support access from anywhere, which prevents academics and students the opportunity to access educational materials at their convenience.
- Some existing models allow focusing on teaching and learning; however, these models use costly applications.
- Most research just investigates the migration process to CC without implementation and evaluation process to assess their results.
- Some existing frameworks are based on other models; however, these frameworks have limited explanatory results.
- Some existing platforms are flexible, but the complexity of communication among the levels is still an open issue.
- Some systems fail to consider social support that allows knowledge exchange among educators.

V. CONCLUSION AND FUTURE WORKS

CC is an emerging technology that provides ICT services for various industries, especially higher education sector. The migration from traditional systems towards CC provides academics and student's access to educational materials anytime and anywhere, and CC enables HEIs to cope with the needs of software and hardware changes rapidly at lower costs. Therefore, the adoption of CC into higher education promotes students' academic level and efficiency. However, the expanded use of CC comes with different significant adoption challenges. Understanding the position of higher education institutions with respect to CC adoption is an essential research area. The existing limitations and challenges in current empirical studies related to this topic are highlighted, and the areas for further investigation are suggested to inform other researchers who might be interested in CC implementation in the higher education field. These suggest essential areas of focus for future CC adoption in higher education research.

The research concluded that there is an urgent need to develop a new web application based on cloud computing, and cover some of gaps in current web applications.

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Defense Mechanisms against Machine Learning Modeling Attacks on Strong Physical Unclonable Functions for IOT Authentication: A Review

Nur Qamarina Mohd Noor
Advanced Informatics School
Universiti Teknologi Malaysia
Kuala Lumpur, Malaysia

Noor Azurati Ahmad
Advanced Informatics School
Universiti Teknologi Malaysia
Kuala Lumpur, Malaysia

Nurul Iman Mohd Sa'at
Advanced Informatics School
Universiti Teknologi Malaysia
Kuala Lumpur, Malaysia

Salwani Mohd Daud
Advanced Informatics School
Universiti Teknologi Malaysia
Kuala Lumpur, Malaysia

Nurazean Maarop
Advanced Informatics School
Universiti Teknologi Malaysia
Kuala Lumpur, Malaysia

Nur Syazarin Natasha Abd Aziz
Advanced Informatics School
Universiti Teknologi Malaysia
Kuala Lumpur, Malaysia

***Abstract*—Security component in IoT system are very crucial because the devices within the IoT system are exposed to numerous malicious attacks. Typical security components in IoT system performs authentication, authorization, message and content integrity check. Regarding authentication, it is normally performed using classical authentication scheme using crypto module. However, the utilization of the crypto module in IoT authentication is not feasible because of the distributed nature of the IoT system which complicates the message cipher and decipher process. Thus, the Physical Unclonable Function (PUF) is suggested to replace crypto module for IoT authentication because it only utilizes responses from set of challenges instead of cryptographic keys to authenticate devices. PUF can generate large number of challenge-response pairs (CRPs) which is good for authentication because the unpredictability is high. However, with the emergence of machine learning modeling, the CRPs now can be predicted through machine learning algorithms. Various defense mechanisms were proposed to counter machine learning modeling attacks (ML-MA). Although they were experimentally proven to be able to increase resiliency against ML-MA, they caused the generated responses to be instable and incurred high area overhead. Thus, there is a need to design the best defense mechanism which is not only resistant to ML-MA but also produces reliable responses and reduces area overhead. This paper presents an analysis on defense mechanisms against ML-MA on strong PUFs for IoT authentication.**

Keywords*—IoT authentication; machine learning; modeling attack; Physical Unclonable Function; low area defense mechanism

I. Introduction

In todays' industrial and civil applications, there are vast number of devices that are connected in a network known as Internet of Things (IoT) [1]. Thus, many issues such as connectivity, power consumption and security have been arisen due to the implementation of IoT. The challenge in implementation of security is important for such devices because they are exposed to attacks. The designated hardware systems must be secured to avoid nullification of secure software implementation. Because of the owned and exchanged data are open for access, any information in the network must be secured to avoid the intervention of compromised data into systems. The infiltration of the malicious data can impair devices and applications especially for the applications that are highly dependent on data veracity, such as described by Barbareschi et al. [2] and Mukhopadhyay et al. [3].

For such applications, authentication becomes one of the most vital security features [3]. Traditional authentication technique for distributed system is typically based on cryptographic modules which are not feasible for implementation in IoT domain. The verifier plays a role as key manager who pre-register every device. The device is expected to use the issued cryptography key to authenticate itself [2]. This method requires message ciphering, each IoT device must comprises of at least a cryptography module, to accomplish security primitives requested by the verifier [3]. The number of devices within IoT system makes the message cipher and deciphers processes difficult to achieve because of the distributed nature of the identity verifier.

Thus, to simplify the authentication process of the IoT devices, silicon Physically Unclonable Function (PUF), has been revisited due to its ability to securely authenticate the IoT devices without requiring messages to be ciphered. The PUF generate unique responses from the set of challenges as the replacement of the cryptographic keys thereby, solve the message cipher and decipher issue. The silicon PUFs employ the unclonability and uniqueness which are produced by the manufacturing process of integrated circuits. These two features are utilized to map a set of challenges (the PUF inputs) to a set of responses (the PUF outputs), which is called challenge-response pairs (CRPs) set.

PUFs with large numbers of CRPs are defined as strong PUFs while PUFs with small numbers of CRPs are classified as weak PUFs. Strong PUFs are originated from delay-based PUFs such as Arbiter PUF, Ring Oscillator (RO) PUF and Glitch (Anderson) PUF while weak PUFs are typically originated form SRAM PUF. The strong PUFs are suitable to be utilized as direct authentication scheme because they produce large set of CRPs thus the unpredictability is high. As for weak PUFs, they are suitable for key generation in cryptographic-based authentication scheme. However, both strong and weak PUFs are exposed to various kinds of attacks such as machine learning modeling attacks (ML-MA), side channel analysis (SCA), fault injection and physical tampering. This paper presents a comparison analysis on various defense mechanisms against ML-MA on variants of strong PUFs.

II. Background of the Problem

Strong PUFs can be directly designed to independently authenticate individual devices without the aid of any cryptographic module. There are two sequential steps to accomplish authentication scheme for devices using PUF [4] as described below:

- Enrollment: A substantial number of randomly chosen challenges is run by the verifier within the device, runs and the corresponding responses is stored in a secure database for future authentication operations [2].
- Verification: An unused challenge is selected by the verifier from the database to obtain a PUF response from the device. The device is verified by the verifier as authentic due to the unclonability property [2] if the response matches the previously recorded one.

To ensure the authentication scheme succeeds, the verifier must collect many CRPs during the enrollment so that it will have sufficient number of CRPs throughout the authentication process. The response provided by the device must be generated within short authentication period as well as be closely matched to the generated response stored by the verifier. Because of this authentication scheme makes use of large CRPs within short authentication period, the interface between verifier and device must be unrestrictedly open to allow the verification to complete faster. This makes the embedded PUFs in devices are subjected to ML-MA because the volume of CRPs can be learnt by the third party to eventually discard the unclonability property and model the strong PUFs [5].

To prevent other parties from building a model out of these PUF, various mechanisms which can be classified into three categories have been proposed. The first category is design-based where the defense mechanism is added in the architectural design of the PUFs such as adding non-linearity using XOR logics [6], [7], modifying transistor-level design [8], exploiting FPGA blocks [9], [10] and analogizing the digital components [11]. The second category is the obfuscation-based where the defense mechanism is performed masking of either challenges [12] or responses [2], [13]. The final category is the access control where the defense mechanism complicates the interface access to protect it from being openly accessed.

Although there are considerable numbers of defense mechanisms available, the best defense mechanism which provides low prediction accuracy with minimal area overhead and generates unique and reliable PUFs responses is still not achieved. All the defense mechanisms resist or at least improve the resiliency of the PUFs against the ML-MA however they come with some shortcomings. In the case of design-based defense mechanisms, adding non-linearity using XOR [6], [7], analogizing the digital components [11] and exploiting the FPGA blocks [4], [10] increase the hardware overhead.

III. PUFs: Variants and Attacks

People and objects are regarded as ‘things’ in Internet of Things. The monitoring and control of these ‘things’ is achieved using devices such as sensors and actuators via communication technologies. The services such as device monitoring, device control, and device search are also delivered in IoT system. The users are provided with applications which have user interface (UI) for controlling and monitoring the IoT system. The security component provides authentication, authorization, message and content integrity in an IoT system. However, security is not apparently highlighted as the crucial component in IoT by most of the vendors of IoT system.

Barbareschi *et al.* [2] stated that PUFs is more suitable for IoT authentication as opposed to the cryptographic algorithm because numerous devices in IoT system causes the message cipher and decipher process difficult to achieve. This is because the identity verifier must work in distributed manner, by enrolling every device. Each device is expected to use the issued key to authenticate itself. Furthermore, the generated keys must be secured on the database managed by the verifier and also on non-volatile memories (NVMs), to circumvent loss of data upon power off.

Mukhopadhyay [14] described the weaknesses of using the crypto-based authentication schemes for IoT-based light-switch system. In this system, smart bulbs with proximity tags, Bluetooth low energy (BLE) signal and a Zigbee-based Ethernet/WiFi-enabled bridge were used as the remote lighting control system to help reduce the energy consumption. The use of Zigbee as the wireless medium which is open by design caused the IoT to be susceptible to eavesdropping, jamming and message injection attacks. Due to the mentioned vulnerabilities, the MD5 hash functions were adopted as the authentication method. The MD5 hash functions were computed based on the device’s MAC address. However, the usage of MD5 hash functions as the authentication method has two significant weaknesses, namely, the secret white list token was not random (clonability) and the MAC addresses are easily recovered (predictability).

Physical Unclonability Function (PUF) on the other hand, is the physical representation of a function that makes it difficult to clone and produces an unpredictable challenge–response pair (CRP) behavior [14]. According to Pappu *et al.* [15], the PUF is ideally hard to characterize or model, but somehow its CRPs are reliably evaluated [16]. Boehm and Hofer [17] described that a PUF utilizes production variability to produce a device-specific output in a form of binary number. A PUF comprises of several components which are defined by local parameter variations. The differences in local parameter variations are known as local mismatches. These local mismatches are merged and directly read out to generate the binary output. Since these local mismatches cannot be controlled externally, a PUF cannot be replicated thereby, it is unclonable. The properties of a PUF are described as follows [3]:

- Reliable: The generated response from the set of CRPs correctly represents the identity embedding function.
- Unclonable: It is hard to construct a procedure to reproduce the set of CRPs in a function.
- Uniqueness: It is hard to compute response from the set of CRPs.

Based on these properties, the PUFs possess several properties like MD5 hash functions, in the sense that they are one way. The fact that the PUF response is unpredictable and unclonable makes the PUF response cannot be predicted or computed thereby, it is suitable to replace the MD5 hash functions. However, PUFs come in many variants which must be evaluated to determine which variant is suitable for IoT authentication.

A. *Variants of PUFs*

PUFs are divided into two variants namely strong PUFs and weak PUFs as shown in Fig. 1. Maes [18] provided a definition on strong and weak PUFs. A PUF is defined as a weak PUFs if it has small challenge set. There is a weak PUFs called a physically obfuscated key (POK) that has only a single challenge. On the other hand, PUFs with a large challenge set are known as strong PUFs and their CRPs are unpredictable whereby it is not possible to build an accurate model of the PUF based on resulted CRPs.

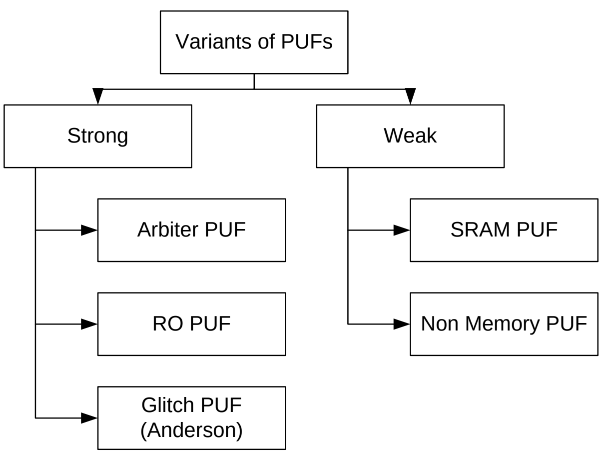

Fig. 1. Variants of PUFs.

1) *Weak PUFs*

Weak PUFs are typically used for storing secret keys as alternatives to non-volatile memories (NVMs) such as ROM and Flash. The characteristics of the weak PUFs were listed by Armknect *et al.* [19] and Ruehmair *et al.* [20] as follows:

- Small and fixed set of challenges where it commonly has only one challenge per PUF instance.
- The access interface to the generated responses is restricted although the adversaries may physically possess the PUF-carrying hardware.

Maes [18] described that weak PUFs are typically designed using intrinsic variations that exist in the integrated circuits. The intrinsic PUFs are cost effective because they are fabricated using standard CMOS logic parts. The first CMOS-based weak PUF was proposed by Lofstrom *et al.* [21] which utilized the threshold mismatch to identify circuits. Tuyls *et al.* [22] developed a PUF based on the capacitance sense from specially applied protective coatings. A PUF which is based on a chip-ID circuit was demonstrated by Su *et al.* [23]. The chip-ID circuit was developed based on cross-coupled devices. The ID was evaluated based on the transition of the cross coupled devices from a metastable state to a stable state which is controlled by process variation. Based on the similarity of this design to the feature of SRAM, there were numerous literatures were inspired to perform research and development of SRAM-based weak PUFs.

SRAM PUFs are developed based on the intrinsic threshold variation of the cross-coupled SRAM cells. The cells are differential in nature thereby they are sensitive to variation (uniqueness) and highly immune to common-mode noise (reliable). Because of these features, the cross-coupled SRAM cells are suitable to be design as PUF. Furthermore, the existence of SRAM in nearly all VLSI circuits makes them highly eligible as PUFs. According to Holcomb *et al.* [24], the CRPs of the SRAM PUFs are generated in the cell during the transition from the off state to an on state. The generated responses are then read out using the standard memory access mechanism [25]. There is also another method of producing CRPs which employs the small amount of data retention voltage of cells instead of the power-up state as proposed by Holcomb *et al.* [26]. Apart from SRAM PUFs, there are other types of weak PUFs were proposed which were either still based on memory or non-memory. Examples of PUFs that are based on the memory design characteristics are Flash [27], DRAM [28] and Memristors [29]. As for the non-memory PUFs, Kumar *et al.* [30] proposed the butterfly PUF which utilizes the cross-coupled latches in FPGAs while Simons *et al.* [31] developed a PUF which is based on bus keepers as an alternative to D Flip-Flop PUF. All the PUFs that were described above only have one designated way to produce the CRPs hence there will be only one challenge per PUF instance.

2) *Strong PUFs*

As opposed to the weak PUFs, the strong PUFs produce complex CRPs because of different kinds of intrinsic variations in the PUF. The generated responses are acquired from numerous physical components therefore a very huge number of possible challenges must be applied to the PUF. The characteristics of the strong PUFs were detailed by Brzuska *et al.* [32] and Chen *et al.* [33] as follows:

- Huge and variety set of challenges which avoid the full read-out of all CRPs, although the adversary may physically possess the PUF for ample amount of time.
- Unprotected challenge-response interface where an adversary may arbitrarily apply challenges to the strong PUF and read out the generated responses.

The strong PUFs originate from delay-based PUFs where random variations on the delay of a digital circuit are measured. Arbiter PUF which was first described by Lee *et al.* [34] is an example of the delay-based PUFs. This type of PUF exploits the variation in the runtime delays of electrical components. The electrical signals in an Arbiter PUF begin their journey through a sequence of k stages where each stage comprises of two multiplexers [35]. The exact path for each signal is determined by k external bits which are applied as one bit per stage. The destination of the electrical signals is ended by a final latch-based arbiter element. Arbiter PUFs with k stages have 2^k challenges where each challenge produce one-bit response. The susceptibility of the Arbiter PUF to ML-MA has resulted to the development of more enhanced version of Arbiter PUF. These enhanced versions commonly utilize non-linearity in the original Arbiter PUFs to resist ML-MA [36]. The examples of the enhanced version of Arbiter PUFs are Feed-Forward Arbiter PUFs [37], [38], Lightweight PUF [39] and XOR Arbiter PUFs [5].

Another type of Strong PUFs is the ring oscillator PUF (RO PUF) which was introduced by Gassend *et al.* [40]. The ring oscillator in their design is a variant of the switch block-based delay line as proposed for the arbiter PUF. A negative feedback is applied to transform the delay circuit into an oscillator. To enable/disable the oscillation, an additional AND-gate in the loop is utilized [41]. To count the number of oscillating cycles during certain time interval, a frequency counter is connected to the oscillating signal. The counter value indicates the oscillating frequency. A simple edge detector processes the oscillating signal to ensure the counter is enabled every time a rising edge is detected [42]. The frequency of the ring oscillator is limited to half the clock because of the use of edge detector. The resulted frequency of equally implemented ring oscillators on distinct devices is considered as a PUF response [43].

There is also another kind of strong PUFs which is developed based on glitch behavior of combinatorial logic circuits. Since internal state does not exist in a pure combinatorial circuit, the input signals have total influence on the steady-state output. However, if the logical value of the input changes, transitional effect such as delays occurred whereby some time is required for the output has its steady-state value. The delays are known as glitches which is determined by the differences in time of arrival for the different logical paths from the inputs to an output signal [18]. The number, shape and occurrence of the glitches on its output signals will be instance-specific and partially random because these glitches are highly influenced by random process variations. Thus, by accurately measured these glitches, their behavior can be utilized as a PUF response.

Anderson [44] developed a glitch-based PUF construction specifically for FPGA platforms which is known as Anderson PUF. Based on the delay variations in the circuit, a custom logical circuit is implemented. The output of this logical circuit is connected to the preset signal of a flip-flop to captures the glitch in case if it occurs. The output of the circuit is treated as the single PUF response bit. By placing many of these logical circuits on an FPGA, many PUF response bits can be produced.

B. Attacks on PUFs

PUFs are exposed to various types of attacks ranging from invasive to non-invasive as depicted by Fig. 2. According to Wachsmann and Sadeghi [45], the invasive attacks require physical modification of the PUF in order to gain deeper knowledge on the PUFs implementation. This type of attack typically affects the weak PUFs because it only has one challenge thereby performing physical modification is possible. As opposed to the invasive attacks, the non-invasive attacks invisibly collect information without being physically harmful to the PUFs. This type of attack usually occurs to strong PUFs because it has huge numbers of challenges thereby data must be gathered and processed. The next section will describe the types of invasive and non-invasive attacks which are encountered by weak and strong PUFs, respectively.

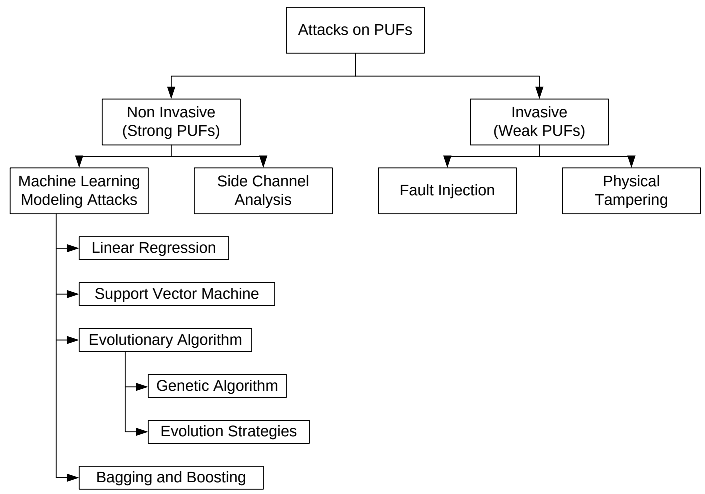

Fig. 2. Attacks on PUFs.

1) Attacks on Weak PUFs

Weak PUFs are subjected to fault injection and invasive attacks. According to Wachsmann and Sadeghi [45], the objective of the fault injection attacks is to induce erroneous behavior in a PUF through internal manipulation and if the manipulation is combined with cryptanalysis, the fault injection attacks can lead to key recovery attacks. There are many ways for the faults to be injected in a PUF such as by injecting transient faults into specific components of the PUF [46], [47] to attain the PUF response or by operating the PUF under extreme environmental conditions which produces decay effects on memory-based PUFs [48], [49]. Another fault-injection attack which is based on the decay effects in volatile memory is presented by Oren *et al.* [50]. This attack manipulates the internal structure of SRAM PUFs which makes them susceptible to cloning.

On the other hand, invasive attacks analyze the PUF hardware to gain the information on the cryptographic secrets stored in a PUF. The reverse engineering and circumvention of active protection mechanisms are the most common forms of invasive attacks. Tarnovsky [51] demonstrated the vulnerability of the algorithms and circuits that are utilized to process the PUF responses to invasive attacks through micro-probing the logic blocks, registers and the bus transfer of PUF devices. As for SRAM PUFs, they are susceptible to extreme operating conditions [52] and physical tampering [53]. As a result, the SRAM PUF hardware can be physically inspected and modified [54]. Furthermore, it was established by Helfmeier *et al.* [53] that upon gaining the response of an SRAM PUF, C_1, a focus ion beam (FIB) can be utilized to alter the circuits of SRAM PUF, C_2 so that C_2 will have a very similar challenge/response behavior as C_1.

2) Attacks on Strong PUFs

Fault injection and invasive attacks on Weak PUFs are less applicable to Strong PUFs. The most relevant attack method for Strong PUFs is known as machine learning-based modeling attack (ML-MA) which was introduced by Ruehmair *et al.* [5]. There are three common machine learning algorithms namely logistic regression (LR), Support Vector Machine (SVM) and evolutionary algorithms (EA) such as genetic algorithm (GA) and evolution strategies (ES) that are used to perform modeling attacks. Abu-Mostafa *et al.* [55] defined LR as a supervised machine learning framework which differs from linear regression in as sense that it outputs a probability between 0 and 1 instead of produces ±1 output. As for SVM, it is a tool that utilizes the optimal margin between vectors to determine the best hyperplane and this method requires computing the distances of input vectors from the hyperplane [55]. According to Saha *et al.* [56], GA is designed to handle integer and binary string solutions by mimicking biological evolution like ES using similar concepts such as reproduction, mutation, recombination/crossover and selection. As for ES, they are utilized to generate population heuristically by adapting the generated population to certain environmental conditions [57]. The data set is randomized to avoid them from linearly separable but the resulted model must be parameterized to ensure the data set is reliable.

As for other machine learning algorithm such as Bagging and Boosting (B & B), it was first used by Vijayakumar *et al.* [7] to perform modeling attacks on strong PUFs. B & B are considered as ensemble meta-algorithm approaches as described by Schapire [58]. Ensemble learning is a technique of merging the predictions from several classifiers to generate a robust classifier. An emerging machine learning algorithm namely deep learning (DL) was also used to perform modeling attack on strong PUFs as proposed by Yashiro *et al.* [8]. They described that DL has superior performance compared to conventional machine-learning methods on a benchmark test in the field of image recognition. DL is defined by Yashiro *et al.* [8] as a multi-layer neural network where it has more than two layers. The output of a layer acts as input for the following layer. This mechanism allows the partition function to be developed which is used to classify input data in accurate and efficient manner.

According to Rührmair *et al.* [5], an adversary first collected vast numbers of CRPs from the strong PUF to perform ML-MA. Next, the adversary infer the behavior of the PUF on the unknown CRPs by combining the numerical method with the internal parametric model of the PUF. The impact of ML-MA is surprisingly massive since all strong PUFs including enhanced version of Arbiter PUFs are still vulnerable to this attack. Modeling attacks are inapplicable to weak PUFs, since they only have one challenge per PUF instance. Another attack that is associated to strong PUF is known as side channel analysis (SCA) [59]. The adversary performs SCA by observing the non-functional metrics of PUF such as the timing information and power consumption to extract information for developing ML-MA. The potential SCA on the design block for processing PUF response such as in fuzzy extractor as discussed by Merli *et al.* [60]. In general, all known SCA on PUF-based systems have some difficulty to attack the main PUF component thereby, they prefer to target the design block that is utilized to process the PUF responses, such as fuzzy extractors. Since SCA alone is difficult to be performed on PUF components, Mahmoud *et al.* [61] proposed to combine ML-MA with SCA to improve attack performance.

IV. IoT Authentication-Strong or Weak PUFs

The basic PUF-based authentication scheme as described by Gassend *et al.* [40], Devadas *et al.* [37] and Barbareschi *et al.* [2] comprises of two phases namely enrollment and verification:

- *Enrollment*: Prior to the deployment, every entity must be enrolled by the verifier. The identity (ID) of every entity is recorded by verifier during the enrollment phase. The verifier also accumulates a substantial subset of CRPs from the device's PUF. The collected challenge-response pairs are stored in the verifier's database (DB) indexed by the entity's ID.
- *Verification*: The verification phase requires the PUF challenge to be sent to the device where the device analyzes its PUF. The replied response is validated by the verifier to check whether it matches to the response it has in its database. If they match, the device is authenticated, otherwise the authentication is rejected. The used CRP is then omitted from DB.

The success of the above authentication scheme relies on the fact that the verifier must collect many CRPs during the enrolment stage so that the CRPs will not run out as emphasized by Halak *et al.* [4]. According to Maes [18], the PUF responses must reproduced within smaller intra distance to ensure that the replied response matches the stored response in the DB without possibility being predicted. Since the successful authentication relies on the large challenges and unpredictability of the responses, it is implied that the suitable type of PUFs for IoT authentication is strong PUFs.

However, the strong PUFs are exposed to the non-invasive attacks as described in Section B. The basic authentication scheme is only secured for a fully unclonable PUFs including the PUFs that are unable to be cloned through machine learning modeling. Strong PUFs which are exposed to ML-MA do not provide secure authentication because the basic protocol cannot differentiate between the real entity with the physical PUF and an adversary with a modeling clone of that PUF. Thus, to be able to provide secure authentication scheme, proper defense mechanisms for strong PUF against modeling attacks and side-channel analysis must be evaluated.

V. Comparison Analysis of Defense Mechanisms Against Attacks on PUFs for IoT Authentication

There are several techniques available as defense mechanism for strong PUFs against non-invasive attacks such as modeling attacks and side-channel analysis. The comparison between the defense mechanisms for strong PUFs against the non-invasive attacks is conducted in Table 1.

TABLE I. SUMMARY OF COMPARISON ANALYSIS OF DEFENCE MECHANISMS

Authors	**Types of Strong PUF**	**Types of Non-invasive Attacks**	**Proposed Defense Mechanisms**	**Strengths**	**Weaknesses**
Goa *et al.* (2013) [5]	Arbiter PUF	ML-MA • LR	Partially obfuscates challenge	Resist attack although millions of CRP are used	Instable generated response
Zheng *et al.* (2016) [11]	DR-PUF based on Analog Arbiter and Glitch PUF	SCA	Uses analog blocks for designing Arbiter PUF	Resist side channel attack	Increase run time and area overhead
Merli *et al.* (2013) [66]	RO PUF	SCA • DPA	Masks the challenge with code word	Prevent first order DPA	Instable generated response
Miao *et al.* (2016) [63]	LRR DPUF based on VLSI interconnect randomness by lithography variations	ML-MA • SVM	Augments the interconnect using cross-coupled logic network	Provide constantly low predictions	Exposed to transistor aging
Tobisch and Becker (2016) [69]	Arbiter PUF	ML-MA • LR	Noise bifurcation (obfuscates response) introduced by Yu *et al.* (2014)	Provide resistance against attacks for large PUF instances	Software model is needed on the server' side
Ye *et al.* (2015) [67]	Arbiter PUF	ML-MA	Obfuscate the logic for path segments selection using cross-coupled inverter	Stable generated responses	Incurs high area overhead
Marten Van Djik and Ruehmair (2014) [70]	Arbiter PUF	ML-MA and SCA	Pre- and post-processing to allow more complex access control	Creates unclonable CRPs	Susceptible to noises
Rührmair *et al.* (2013) [6]	Arbiter PUF	ML-MA • LR • ES	• Increasing challenge bit length • Adding non-linearity	Improves resistance against machine learning attacks	• Instable generated response • Increased hardware overhead
Barbareschi *et al.* (2015) [2]	Enhanced Anderson PUF	ML-MA	Hides PUF responses using AES	Provide better unpredictability	Incurs high area overhead
Mukhopadhyay (2016) [14]	LSPUF based on Arbiter PUF	ML-MA • ES	Fuses the access point to CRPs	Increases complexity to build ML model	Not directly secured against ML-MA
Wallrabenstein (2016) [68]	RO-PUF	ML-MA	Applies elliptic curve crypto module construct to obfuscate responses	Provide better unpredictability	Incurs high area overhead
Vijayakumar *et al.* (2016) [7]	Arbiter PUF	ML-MA • SVM • LR • B & B • ES	Non-linear XOR logic function with high cardinality / entropy	Provide better resistance against all attacks especially B & B attacks	Incurs high area overhead
Capovilla *et al.* (2015) [62]	Arbiter PUF	ML-MA and SCA	Configures gate size in accordance to arbiter elements	Generate stable responses	Exposed to transistor aging
Kumar and Burleson (2016) [64]	Feed Forward PUF	ML-MA + SCA	Reduces number of stages/loops	Exhibit better unpredictability	Induces error in CRPs
Yashiro *et al.* (2016)	Arbiter PUF	Deep Learning	Tightens the layout conditions to make P and R difficult	Has higher tolerance against ML-MA	Instable generated response
Yu *et al.* (2016) [8]	XOR Arbiter PUF	ML-MA and SCA	Employs lockdown protocol which requires server's permission to obtain new CRPs	Makes the PUF exponentially difficult to learn	Incurs high area overhead
Zhang *et al.* (2016) [71]	Enhanced Anderson PUF	ML-MA	Adds reconfigure ability to the PUF design	Provides high CRP uniqueness	Incurs high area overhead
Idriss *et al.* (2016) [15]	Arbiter PUFs	ML-MA	Hide CRP using cryptographic functions	Provide high unpredictability	Incurs high area overhead
Amsaad *et al.* (2016) [10]	RO PUF	ML-MA • SVM • GA	Exploit FPGA resources to build multi-stage structure	Improves CRP space in terms of uniqueness and reliability	Incurs high area overhead
Zalivaka *et al.* (2017) [12]	Arbiter PUF	ML-MA • SVM • LR	Obfuscates the strong challenges using FPGA resources	Decrease the ML prediction rate	Instable generated response

Based on Table 1, the defense mechanisms that were proposed can be divided into three categories namely design, obfuscation and access control. The design category consists of adding non-linearity using XOR logics [6], [7], configuring transistor's gate sizes [62], augmenting interconnects [63], tightening the layout condition [8], exploiting FPGA resources and reconfigurability [9], [10] and modify current PUF design blocks by using analog blocks [11] and reducing feed-forward stages [64]. These defense mechanisms provide resistance to machine learning modeling attacks however they come with certain shortcomings. Adding non-linearity using XOR logics, modifying the PUF design blocks using the analog blocks and exploiting FPGA resources and reconfigurability incur high area overhead. Configuring transistor's gate sizes and augmenting interconnect make the PUF to be susceptible to the transistor aging. Tightening the layout condition and reducing the feed-forward stages generate instable PUF responses.

As for the obfuscation category, the obfuscation is performed either on PUF challenges or responses. The simplest obfuscation technique for PUF challenges was proposed by Rührmair *et al.* [6] where the challenges' bitlength is increased. Goa *et al.* (2013) partially obfuscated the PUF challenges and Zalivaka *et al.* [65] segregated between strong and weak challenges, eliminated the weak challenges and obfuscated the strong challenges using FPGA resources to successfully resist the ML-MA. As a countermeasure against SCA, Merli *et al.* [66] masked the challenges with code word. This technique was able to prevent first order DPA. However, all the obfuscations on the PUF challenges generated instable response. Ye *et al.* [67] solved this issue by instead of directly obfuscating the challenges, the obfuscation was performed the logics for path segments selection for PUF challenges. However, this solution came with the cost of high area overhead. The obfuscation on the PUF responses is typically performed using the crypto module such as AES [2], [15] and elliptic curve [68]. These techniques increase the unpredictability of the PUFs, however, still they incurred high area overhead. There is also another technique of obfuscating the PUF responses which utilizes noise bifurcation [69]. The downside of this technique is that the software model must be developed and stored on the server's side.

The third category is the access control in which Djik and Rührmair [70] adding the complexity to the access control by performing pre- and post-processing of the CRPs. However, this technique makes the PUFs susceptible to noises. Mukhopadhyay [14] temporarily fused the access point to CRPs to increase the complexity to build ML model but the PUFs are still not directly secured against ML-MA. Another defense mechanism related to access control is developed by Yu *et al.* [71]. The authentication using PUFs was performed by employing lockdown which requires server's permission to obtain new CRPs. This technique makes the PUF's CRPs exponentially difficult to learn but it comes with the cost of high area overhead.

VI. Conclusion

There are several defense mechanisms against non-invasive attack particularly ML-MA on variants of strong PUFs for IoT authentication. All these defense mechanisms were claimed to provide resistance or at least improve resiliency of the strong PUFs against ML-MA. Each defense mechanism has their own strengths and weaknesses. The most apparent weakness that they exhibited is either the area overhead is high or the generated PUF responses are instable. The issues regarding PUF responses and area overhead that were incurred by these defense mechanisms must be solved to ensure that the selected variant of strong PUFs for IoT authentication is at their best performance. Thus, there is a gap in determining the most suitable variant of strong PUF that provide best defense mechanism that solve the issue of unreliable responses and high area overhead. To resolve these issues, a suitable variant of strong PUF with reliable responses and low area overhead must be developed for a quality IoT authentication.

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The Ethical and Social Issues of Information Technology: A Case Study

Ehsan Sargolzaei
Computer Engineering Department, Faculty of Engineering
University of Zabol
Zabol, Iran

Mohammad Nikbakht
Computer Engineering Department, Faculty of Engineering
University of Zabol
Zabol, Iran

***Abstract*—The present study is conducted among 283 students from University of Zabol to identify the harm and ethical and social issues in the field of information technology and to classify the immoral practices that students are doing in this field. First various important issues in the field of IT in the social and ethical areas are discussed. Then the cases considered as the most commonly used immoral activities, are selected for evaluation, and the participants ranked these activities according to the method presented in the questionnaire. These activities are examined and analyzed descriptively by SPSS program, reliability of the questionnaire is measured by Cronbach's alpha coefficient, Bartlett Test of Sphericity and KMO index and the validity of the results is verified using T-test and the results are ranked based on the first performance that happens frequently and the last performance that happens rarely or never. Finally, a set of strategies are presented for preventing ethical abuse in the field of Information Technology so that the challenges are reduced.**

***Keywords*—Information technology; ethical and social issues; unethical practices; students**

I. Introduction

New advances particularly in the field of information technology have brought new scientific gains to humans but it should be noted that the entry of new scientific and technological fields will always have ethical issues and limitations. One of the interesting and, of course, new topics in the field of information technology science is computer ethics or IT ethics. The study of computer ethics has long been considered by the researchers. Today, in the digital age, the society is dependent on computers in almost all its affairs, and the study of ethics in the field of computer and information technology must always be considered.

The growth and development of the Internet has made it possible to store a large number of individuals' personal data by relying on advanced information systems and the abuse of personal data and privacy violations in the field of information technology is increasing [1].

The lack of scientific integrity in educational environments that make the most use of technology is an issue that should be considered. Illegal downloading of software is common among all social classes specially the students. The use of social networks is an inseparable part of the lives of many people and the nature of students. These cases have different effects on their lifestyle, especially on their academic performance and the length of their studies [2], [3].

On the other hand, the number of unethical sites is rising every day and the conditions for access to these sites are easier than before and the mean age of people who visit these sites is reduced. Being exposed to the unethical sites also has the dangers of high-risk sexual behavior, social dilemmas and mental and psychological problems. Communicating with anonymous people and visiting them is increasing [4].

A large percentage of users are exposed to moral damages and IT abnormalities, and having a virtual identity has become a commonplace cause of many social abnormalities. The phenomenon of Internet addiction has long been considered in the developed countries as one of the consequences of the ever-increasing development of the electronic communications network and has caused various harms to the individual, family and society. The excessive use of social networks can lead to addiction and is not tolerated by many physical communities. The theft of software, films, music, etc. with copyrights has become common in some societies.

Unauthorized access to the systems (hacking) is done using different and new methods and is increasing every day. Today hackers have posed the greatest challenge against IT ethics and with a widespread violation, they make numerous attempts to influence the commercial and banking accounts of individuals and try to violate individuals' privacy [1].

Many computer games are violent and stimulate aggressive antisocial behavior in addition to violent thoughts and feelings.

Today, forging digital documents such as counterfeiting digital signatures, digital images, etc. is an important topic in the field of information security and computer ethics. Online gambling (using online websites where members can participate in a variety of games without having to be present at the site, in which everything is done online from opening an account to transferring funds, withdrawals, playing games, etc.) is increasing.

Cases such as cyber bullying and communicating with anonymous individuals, visiting them, sharing the stimulating content on the Internet, and sharing personal information on the Internet have been recognized as the dangers of Internet communications in the new era [2].

All of these cases are examples of issues that affect ethics in information technology and it is necessary to rank such issues in terms of society in order to provide a better insight to provide strategies and programs in which negative measures are converted to the positive affairs or ethical issues in the field of information technology are observed.

The remainder of this article is organized as follows. Section 2 presents related works. In Section 3, details the significance and objectives of the study, while Section 4 outlines the methodology and the sampling collection. The data analysis and results are provided in Section 5, the discussion and the concluding remarks are given in Section 6 and finally, the future research is discussed in Section 7.

II. Related Works

The high use of the Internet has led to the negligence of other important parts of life, including sleep, work, and academic achievement. Users in the Internet environment can be anonymous and engage in behaviors that are inappropriate in most physical communities. On the other hand, providing fast, cheap and convenient access to the unethical sites can be considered as a disadvantage of the use of the Internet. [5]

Studies have shown that a high percentage of employees in the workplace use the Internet for non-work purposes. Meanwhile the most common non-work activities are: visiting the chat rooms, sports websites and stock investment websites [6]. Apart from all of this, computers and the Internet have the potential to violate the privacy of users by hackers [7], [8]. Research shows that 75 percent of American children are willing to share their personal data and information with other Internet users in exchange for access to services and products provided on the Internet, which can be very dangerous [4].

In 2011, a research is conducted on the impact of virtual social networks on the academic achievement of students at Birjand University of Medical Sciences in eastern Iran. The result of this study showed that there is an inverse relationship between the use of social networks and the student's mean scores which is similar to the results of other research in this field. In this study, the most time spent on social networks is over the nights [9].

A research is conducted on the use of the Internet and social isolation among Iranian students. The study found that people who use the Internet and are addicted to social networks are faced with social isolation. It has also been shown that Internet addiction is 8.3% higher among Iranian students and the students who are addicted to the Internet feel lonelier and have less confidence than normal users [10].

Mobile cameras despite their useful applications could affect the privacy of others in public places. Although mobile phones have actually changed today’s lifestyle, almost all of them are equipped with high-quality digital cameras. These cameras can capture images of people without their consent, violate their privacy, be published by the Internet and become available to others [11].

A study conducted in the United States of America in 2012 among the men showed that exposure to unethical sites has led to a high-risk sexual behavior among them [12].

Many investigations are conducted on the issue of sexually transmitted content since 2009 in many countries of the world including the United States, the United Kingdom, Australia, Canada, China and the Czech Republic. It should be noted that researches conducted in National Campaign for the Prevention of Juvenile Injuries and Pregnancies in the United States have presented significant outcomes in the prevalence of sexting among young Internet and mobile phone users [4], [13].

Aside from an easy access to these websites, animated computer games have also been developed that allow online gaming with the opposite sex; therefore, it is clear that a wide range of users, including children, can easily become addicted to the computer games while these games can have a lot of destructive effects [5].

On the other hand, computer games are often associated with adverse social phenomena such as violence and various types of addiction among the adolescents. A wide range of computer games provokes violence indirectly. Violent computer games not only stimulate violent thoughts and feelings, but also provoke aggressive and antisocial behaviors [14], [15].

III. Significance and Objectives

Given that ethical abuse in the field of information technology is increasing, it is necessary to analyze these cases. The roots and underlying causes of the problems should be considered in order to provide solutions to prevent them. In this study it is attempted to examine the ethics of information technology in the academic fields, identify the existing challenges, and finally provide solutions to prevent them because the author believe that if this research is conducted in an academic setting, these cases can be more precisely reviewed and it is possible to provide the proposed training and solutions in a broader manner. Then in the future works this issue will be discussed in other age groups as well as other social classes. The main goal in this research is to examine the ethical challenges in the field of information technology and provide possible solutions for the improvement of the situation based on the achieved results.

IV. Methodology

A. Measurement

The tool for measuring variables and indicators in this research is the questionnaire. In other words, by filling out the questionnaire, people’s ideas are recorded and measured. To collect field information and complete the questionnaire, the questionnaire is designed online and provided to the statistical population. All answers to each question as well as the date and time of response are saved in the Excel file. Then SPSS software is used to analyze data. In this research the descriptive and statistical analyses of the software are used and the results are assessed using the output of this software.

The questionnaire is designed so that all unethical cases can be considered in terms of student performance. Questionnaire items are divided into two parts. The first part included the items that have case options and need to be analyzed descriptively, and the second part included the items based on the Likert scale that each one addressed an index and analyzed statistically. Using the Likert scale [16], one can assign points to each of these questions and finally rank their questions and indices. The final score of the questions and indices is also calculated by averaging each one. Comparing this mean shows which question or index has the highest number of agreements and ranks them from highest to lowest, respectively. It should be noted that the calculation of the score and the index is only possible in the case of questions that the Likert scale has been used in the response options and for other questions the descriptive statistics are applied.

Responses are based on 5-point Likert scale. Each respondent was requested to indicate his/her stance on each ethical statement as 1 (strongly agree), 2 (agree), 3 (not sure/undecided), 4 (disagree) or 5 (strongly disagree).

Now, with this valuation method it is possible to calculate the indices obtained by the combination of several questions by means of averaging the results. For example, to calculate the Violent Computer Games Index, which includes the items 36 and 37, it is enough to compute the mean value of the answers to these two questions to get the index number. Table 1 presents the challenges presented in this study with items related to these issues (first part items - descriptive) and Table 2 presents the second part items including the items based on the Likert scale.

TABLE I. ETHICAL ISSUES, NUMBER OF STATEMENTS AND QUESTIONS USED IN THIS SURVEY (FIRST PART ITEMS - DESCRIPTIVE)

Ethical issues	**Number of questions**	**Questions**
Computer addiction	2	1, 2
Addiction to social networks	4	3, 4, 5, 6
Addiction to unethical sites	3	7, 8, 9
Violent computer games	2	10, 11

TABLE II. ETHICAL ISSUES, NUMBER OF STATEMENTS AND QUESTIONS USED IN THIS SURVEY (SECOND PART ITEMS - THE ITEMS BASED ON THE LIKERT SCALE)

Ethical issues	**Number of questions**	**Questions**
Privacy violation	6	12, 13, 14, 15, 16, 25
Negative behavioral and personality impacts	3	17, 18, 26
Formation and promotion of gossip and fake news	2	19, 21
Anti-religious propaganda (in cyberspace)	1	20
Addiction to social networks	2	22, 23
Verbal attacks	2	24, 27
Violation of ethical principles using a mobile phone camera	2	25, 35
Online theft	4	28, 29, 30, 31
Hacking	2	31, 34
Copyright violation	2	32, 33
Forging digital documents	1	33
Violent computer games	2	36, 37
Online gambling	1	38

B. Sampling and Data Collection

The statistical population of this study includes 283 students including 147 male and 136 female undergraduate, postgraduate and PhD students in University of Zabol. Students' participation in answering the questionnaire is done voluntarily and completely anonymous. It is also emphasized that participants' information will be used solely for research and research purposes and will be completely confidential.

V. DATA ANALYSIS AND RESULT

A. Methods of Analysis

Reliability is one of the technical features of the measurement tools. The concept of reliability is that the measurement tools give the same results under the same conditions. Different methods are used to calculate the reliability coefficient of the measurement tools including Cronbach's Alpha method [17]. This method is used to calculate the internal coordination of the measurement tools such as questionnaires or tests that measure different characteristics. In such tools, the answer to each question can receive different numeric values. The zero value of this coefficient indicates unreliability and +1 denotes complete reliability. The reliability of the questionnaire is evaluated using Cronbach's alpha coefficient. The Cronbach's alpha value of the research questionnaire is 0.731 which indicates the desirable reliability of this questionnaire.

There are several methods for assessing the validity of the questionnaire. That Bartlett Test of Sphericity [18] and KMO[1] index [19] are used. Bartlett's test examines the hypothesis that the observed correlation matrix belongs to a population with unmatched variables. Also, the KMO index is a method that takes a value between zero and one and the closer value of which to one indicates the higher detailed correlations between the variables (questionnaire items) and the higher validity. Table 3 presents the Bartlett Test of Sphericity and KMO index results.

In the present study, Bartlett Test of Sphericity is significant at a significance level of 0.05 because significance $P < 0.05$ and also the KMO value is acceptable. Therefore, the questionnaire has construct validity.

B. Demographic and Professional Profiles

Frequency table of respondents' educational level is presented in Table 4.

TABLE III. KMO AND BARTLETT'S TEST

Kaiser – Meyer- Olkin Measures of Sampling Adequacy	**0.621**
Bartlett's Test of Sphericity	
Approx. chi- square	1002.9
Significance	0.001

[1] Kaiser-Meyer-Olkin

TABLE IV. FREQUENCY TABLE OF RESPONDENTS' EDUCATIONAL LEVEL

	Number	Percent
PhD	35	12 %
Master's degree	29	10 %
Bachelor's degree	209	74 %
Associate's degree	8	3 %
NA	2	1 %
sum	283	100 %

As it can be observed undergraduate students form a significant portion of the statistical population. Also, most students entered the university in 2012 and 2015. 52% of the statistical population is the male and 48% is female that the difference in the number of male and female respondents is not significant.

C. Analysis of Achieved Results

Since the size of the statistical society is large enough (more than 30), the use of parametric tests such as T is an optional example. Therefore, in this study, T-test [20] was used to check the accuracy of the results. In Tables 5 and 6, the first (first part items - descriptive) and second (questions containing the Likert scale) part items are presented along with the corresponding indices.

The main items are the ones that have options based on Likert scale. Each of these questions will also examine a specific index. Given that the options of these questions include Likert scale, one can assign a specific point to each of these questions according to the answers and, finally, the items and their indices are ranked. In this section, the statistical description of the answers provided to each question is discussed. Table 6 summarizes the results regarding the first objective of the study, namely to addresses the respondents' attitudes towards ethical IT issues, also known as ethical orientation.

In this section, the mean score is calculated among the main items with Likert scale and it is indicated from the highest to the lowest value in the table below. The items with higher score are the one that have been more agreed than others; thus the first questions are the immoral actions with the highest frequency and the last questions are the immoral actions with the lowest frequency. Ranking the main questions of the questionnaire is listed in Table 7.

TABLE V. ETHICAL ORIENTATIONS OF RESPONDENTS TO ETHICAL ISSUES IN IT (QUESTIONS IN THE FIRST PART OF THE QUESTIONNAIRE)

	The purpose of the Questions		The obtained result
1	The rate of using a computer and checking addiction to it	15 %	No computer addiction
2	The reason for using a computer	48 %	Addiction to the computer for entertainment and recreation
3	The rate of using virtual social networks	65 %	Addiction to virtual social networks
4	The most common reason for using the virtual social networks	3 %	Interaction with friends and relatives, and no connection with strangers and finding new friends
5	Membership period in the virtual social networks	67 %	Before entering university
6	Times of using the virtual social networks	74 %	Night
7	Access to unethical sites through virtual social networks	37 %	Significant access
8	Investigating access to unethical sites over the Internet	40 %	Significant access
9	The rate of use of obscene images and videos	8 %	No addiction to unethical sites
10	Checking the amount of computer games used and addiction to them	42 %	No addiction to computer games
11	Favorite style for computer game	48 %	Arcades and sports games

TABLE VI. ETHICAL ORIENTATIONS OF RESPONDENTS TO ETHICAL ISSUES IN IT (QUESTIONS IN THE SECOND PART OF THE QUESTIONNAIRE- INCLUDE LIKERT SCALE)

No	Questions	Mean	SD	SA	A	I	D	SDi	NA
1	By communicating with strangers in cyberspace and visiting them...	2.54	1.06	4	10	45	19	22	0
2	By sharing personal information on the Internet or virtual social networks...	2.26	1.14	4	11	22	32	31	0
3	I allow people with unknown true identity to access my information.	1.73	0.99	3	4	9	30	54	0
4	Many profiles on social networks are fake and compromise my privacy	3.65	1.13	25	37	25	7	7	0
5	I check pictures and personal information of others without knowing whether they are ok with that or not	2.59	1.09	4	18	30	31	17	0
6	I share many topics that I am not interested in the real world	2.48	1.08	3	14	33	28	22	1
7	Social networks have led to social isolation in me	2.63	1.17	8	17	21	38	26	0
8	Most of the cyberspace shared content is unrealistic	3.49	0.93	12	43	30	14	2	0
9	Anti-religious propaganda is very common in cyberspace	3.57	1.05	18	41	25	13	4	0
10	I have shared the news in cyberspace that I am not sure whether they are real or rumor	2.11	1.08	3	11	15	38	34	0
11	Social networks and the Internet have led to lack of academic progress in me	2.79	1.22	9	23	20	32	15	0
12	Social networks and the Internet have led me to neglect other important parts of life, including sleep, work, and so on	3.05	1.20	10	35	16	30	10	0
13	With verbal attacks in cyberspace...	1.79	0.93	1	5	14	33	48	0

14	My friends' consent is <u>not</u> necessary in sharing their photos with me in cyberspace	1.87	0.97	3	4	14	37	43	0
15	I feel lonely in cyberspace and have lower confidence	2.31	1.08	4	10	26	34	26	1
16	On the Internet I can express my opinions freely and without any fear	3.47	1.03	16	35	31	14	3	0
17	I am not willing to pay for the software, movies, music, etc., with copy rights	3.22	1.18	18	23	28	25	6	0
18	I download software, movies, music, etc., with copy rights that are presented for free	3.76	1.04	25	42	23	5	5	0
19	I have software, movies, music, etc., with copy rights I have paid for but I will share them with other for free	3.62	0.96	16	47	23	12	2	0
20	If needed, I would be willing to pay and enter my bank account information from the bank portals about the authenticity of which I am not sure	2.15	1.08	3	10	16	38	32	1
21	I am more inclined to get free articles than similar articles that are offered on a paid site	3.66	1.05	22	38	25	9	4	2
22	I use the research work or artwork of another person without mentioning the source and reference	2.48	1.20	6	16	20	32	23	2
23	If necessary, I would like to use decoding software to retrieve the information resources of others	2.09	1.12	3	10	17	32	37	1
24	I use my mobile camera in any public place	2.90	1.24	11	21	30	21	16	1
25	Violent computer games are more appealing to me	2.73	1.32	9	23	22	19	25	2
26	Violent computer games provoke violent thoughts, feelings and antisocial behaviors in me	2.77	1.28	11	17	28	22	20	2
27	I make money through computer games and online gambling	2.41	1.21	5	15	25	23	30	2
Mean of all statements: 2.74									
SD: Standard deviation, SA: Strongly agree (%), A: Agree (%), I: Indifferent (%), D: Disagree (%), SDi: strongly disg. (%)									

TABLE VII. RANKING THE MAIN QUESTIONS OF THE QUESTIONNAIRE

No	Questions	Mean
1	I download software, movies, music, etc., with copy rights that are presented for free.	3.76
2	I am more inclined to get free articles than similar articles that are offered on a paid site.	3.66
3	Many profiles on social networks are fake and compromise my privacy.	3.65
4	I have software, movies, music, etc., with copy rights I have paid for but I will share them with other for free.	3.62
5	Anti-religious propaganda is very common in cyberspace.	3.57
6	Most of the cyberspace shared content is unrealistic.	3.49
7	On the Internet I can express my opinions freely and without any fear.	3.47
8	I am not willing to pay for the software, movies, music, etc., with copy rights.	3.22
9	Social networks and the Internet have led me to neglect other important parts of life, including sleep, work, and so on.	3.05
10	I use my mobile camera in any public place.	2.90
11	Social networks and the Internet have led to lack of academic progress in me.	2.79
12	Violent computer games provoke violent thoughts, feelings and antisocial behaviors in me.	2.77
13	Violent computer games are more appealing to me.	2.73
14	Social networks have led to social isolation in me.	2.63
15	I check pictures and personal information of others without knowing whether they are ok with that or not.	2.59
16	By communicating with strangers in cyberspace and visiting them...	2.54
17	I share many topics that I am not interested in the real world.	2.48
18	I use the research work or artwork of another person without mentioning the source and reference.	2.48
19	I make money through computer games and online gambling.	2.41
20	I feel lonely in cyberspace and have lower confidence.	2.31
21	By sharing personal information on the Internet or virtual social networks...	2.26
22	If needed, I would be willing to pay and enter my bank account information from the bank portals about the authenticity of which I am not sure.	2.15
23	I have shared the news in cyberspace that I am not sure whether they are real or rumor.	2.11
24	If necessary, I would like to use decoding software to retrieve the information resources of others.	2.09
25	My friends' consent is <u>not</u> necessary in sharing their photos with me in cyberspace.	1.87
26	With verbal attacks in cyberspace...	1.79
27	I allow people with unknown true identity to access my information.	1.73

D. Checking the Achieved Results by using a Single-Sample T Test

In order to evaluate the results the mean score assigned to each index is examined and using a single-sample T test, the difference between the mean score and the value of 3 (the mean value of the answers of each question) is measured. In Table 8, the analysis of each index is presented.

TABLE VIII. T TEST RESULTS FOR THE ETHICAL ISSUES' INDICES IN THE FIELD OF INFORMATION TECHNOLOGY ETHICS

Index	Mean	SD	D	Statistics T	significance P	CI
violation of privacy	2.44	0.50	- 0.56	- 15.065	0.001	2.37 to 2.51
negative behavioral and personality effects	2.48	0.80	- 0.52	- 8.844	0.001	2.36 to 2.59
rapid formation and spread of rumors and false news	2.80	0.69	- 0.20	- 3.873	0.001	2.70 to 2.90
Anti-religious propaganda in the cyberspace	3.57	1.05	- 0.57	7.354	0.001	3.42 to 3.72
addiction to social networks	2.92	1.08	- 0.08	- 0.994	0.332	2.76 to 3.08
verbal attacks	2.63	0.67	- 0.47	- 7.418	0.001	2.53 to 2.73
online theft	3.19	0.57	- 0.19	4.435	0.001	3.11 to 3.28
Hacking	2.13	0.80	- 0.87	- 14.872	0.001	2.01 to 2.24
Copyright violation	3.05	0.92	- 0.05	0.725	0.469	2.92 to 3.18
forging digital documents	2.44	1.23	- 0.56	- 6.132	0.001	2.26 to 2.62
ethical abuse of the camera	2.38	0.80	- 0.52	8.943	0.001	3.41 to 3.64
interest in violent computer games	2.71	0.99	- 0.29	- 4.009	0.001	2.56 to 2.85
online gambling	2.41	2.41	- 0.59	- 6.511	0.001	2.23 to 2.59
D: The difference between the mean score and the value of 3, CI: 95% confidence interval for the average response						

For the privacy violation index, the mean value of the scores is 2.44, which is 0.56 units less than the value of 3, and the significance of the t-test at the 95% confidence level (Significance $P < 0.05$) indicates that the mean response of the individuals to the privacy violation component has a significant difference with the value of 3 and according to the 95% confidence interval, the mean response rate in the community with a 95% probability is within the range of 2.37 - 2.51. Since the questionnaire options are defined so that the responses indicating the violation of the privacy of others tend to the large numbers (greater than 3) it is concluded that the violation of privacy is low among the students of University of Zabol because firstly, the mean response of individuals is less than 3 (to the "completely opposite" or non-violation of privacy), and secondly, the mean value is significant compared to the number 3 (Significance $P < 0.05$).

Similar to the abovementioned analysis and the data in Table 3, the results in other indicators were obtained as follows:

- The level of negative behavioral and personality effects of information technology is low among University of Zabol students.
- The rate of rapid formation and spread of rumors and false news in students of University of Zabol is lower than the mean level.
- According to the students' opinion of the University of Zabol, the level of Anti-religious propaganda in the cyberspace is very common and is at a high level.
- The amount of verbal attacks among the students at University of Zabol is lower than the mean level.
- The rate of online theft in students in University of Zabol is higher than the mean level.
- The interest in hacking is low among University of Zabol students.
- The amount of forging digital documents is low among University of Zabol students.
- The degree of ethical abuse of the camera is low among University of Zabol students.
- The level of interest in violent computer games is lower than average among University of Zabol students.
- Interest in online gambling is low among University of Zabol students.

For the addiction to social networks index, the mean value of the scores is 2.92, which is 0.08 units less than the value of 3, and the insignificance of the t-test at the 95% confidence level (Significance $P \geq 0.05$) indicates that the mean response of the individuals to the privacy violation component has not a significant difference with the value of 3 and according to the 95% confidence interval, the mean response rate in the community with a 95% probability is within the range of 2.76 - 3.08. it is concluded that The degree of addiction to social networks is average among University of Zabol students because according to the above test the mean value is not significant in comparison with the number 3 (Significance $P \geq 0.05$).

- The degree of Copyright violation is average among University of Zabol students.

E. Ranking the Ethical and Social Issues Indices in the Field of Information Technology

In the previous sections, the rate of each index was studied among students of University of Zabol. Here the Friedman test [21] is applied to rank these indices. In Table 9, the test result is presented.

Considering that the Significance P is less than 0.05, the above hypothesis is rejected at the significance level of 0.05 which means that the rate of ethical and social issues indices in the field of information technology is different among University of Zabol students. Table 10 shows the mean values of each factor, according to which "anti-religious propaganda is very common in cyberspace in the view of students from the University of Zabol. Also hacking has the lowest rate among University of Zabol students.

TABLE IX. FRIEDMAN TEST FOR RANKING THE ETHICAL AND SOCIAL ISSUES INDICES IN THE FIELD OF INFORMATION TECHNOLOGY

Hypothesis	Test statistics	Significance P
The rate of ethical and social issues indices in the field of information technology is the same among University of Zabol students	400.05	0.001

TABLE X. THE RANKING THE ETHICAL AND SOCIAL ISSUES INDICES IN THE FIELD OF INFORMATION TECHNOLOGY

rank	Ethical and social issues indices in the field of information technology	Ave. ranking
1	Anti-religious propaganda in the cyberspace	9.96
2	Online theft	9.28
3	Copyright violation	8.73
4	Addiction to social networks	7.78
5	Rapid formation and spread of rumors and false news	7.58
6	Interest in violent computer games	7.24
7	Verbal attacks	6.79
8	Online gambling	6.08
9	Negative behavioral and personality effects	5.97
10	Forging digital documents	5.81
11	Ethical abuse of the camera	5.75
12	Violation of privacy	5.67
13	Hacking	4.35

VI. DISCUSSION

According to the conducted studies and the results obtained from this study, it can be concluded that ethics in information technology can be trained to influence the individuals. Given that there is no mandatory syllabus for students in bachelors and master and PhD course in Iran on ethical issues in information technology, such a program seems essential to cope with the ethical challenges of IT. Previous investigations also prove this claim [22]-[24].

In some cases, gender has a significant impact on the ethics of information technology, which can be due to local traditions, beliefs and cultural factors in Islamic countries. From a traditional and cultural point of view, women are expected to have different values than men; therefore, they have different moral behavior compared to men in different conditions. As reported in [25] and [26], women are expected to follow cultural and family values and obey tough constraints.

In terms of intellectual property, the results showed that the policies of Internet Service Providers (ISPs) and, in general, the Internet and domestic policies in some countries, such as Iran, are different than other countries. In Iran, strict software policies are not enforced, and individuals can download software and related items freely, while these policies are strict in some countries and people cannot access these data easily. Also the effective codes of ethics as well as correct policies should also be considered. In this section, the research results are consistent with other researchers' findings [27]-[31].

Two points of view can be considered for copyrights; the first point is that copyrights are incentives for creative production. The second point is that copyright is considered as a commodity for the consumer, who seeks to use it for free or at a negligible cost. Using this argument, it can be concluded that developed countries are struggling to secure the first view to have the copyright of their own works; on the other hand, in developing countries there is an attempt to reach a second view to have access to the copyright easier and at a lower cost. As the results of this study suggest, the copyright in Iran is not to be respected as well, and individuals have free access to software and some other copyrighted works free of charge. This challenge also requires growth, education and cultural developments. Also, the infrastructures ness to be corrected and punishments should be considered for the violation of copyright.

There are no significant differences regarding privacy issues at different points as well as gender which indicate that privacy is a concern for all individuals. The results of this study also confirm this issue. Of course, the study also shows that female students are more concerned about their privacy. IT professionals or computer and IT students, considering that they have more information on this subject, are more likely to respect privacy-related issues, which also refers to the training of individuals. In order to discuss the privacy of access to data, IT strategies, infrastructures and platform must be properly defined and implemented. Previous studies confirmed the results of this research in this regard [32], [33].

In this section a set of strategies and training for controlling unethical activities in the field of information technology are presented at the University of Zabol. It is hoped that considering the mentioned solutions in the previous section and these strategies and trainings the ethical and social issues will be respected in the field of information technology and their challenges are reduced.

- Addiction to social networks, cyberspace and computers:
  - To create real and effective recreation and entertainment instead of virtual entertainments for students.
  - To reduce addiction to social networks, cyberspace and computers at night, the false policies of some companies should be eliminated. For example the lower cost of the Internet at night should be eliminated by these companies and instead of free download at

night, this feature is provided during the day at a lower cost rather than the night.

- Family control and monitoring can also be an effective factor in this regard.
- Addiction to online unethical sites:

  - The most important and effective way to reduce addiction to unethical sites is to educate people about the dangers of addiction to it. If people become aware of the consequences and risks of being exposed to online unethical sites, the likelihood of such addiction is reduced significantly.

  - There are conditions for non-access to such websites. In Iran, the filtering rule is an example of such conditions which is unfortunately not very successful.
- Addiction to violent computer games:

  - Creating recreational activities, such as creating diverse sports halls, green spaces and parks, etc., is an appropriate solution to fill the students' leisure time or their lack of access to such games.

  - Cultural development on the use of such games so that the hours spent on the computer games is limited.

  - Localization of computer games, which means the production and presentation of domestic computer games rather than the supply of games by the other countries. This solution can be effective due to the match between the computer games and the culture and beliefs of the country of residence.
- Secularization, anti-religious propaganda and blasphemy:

  - Informing people and teaching religious issues

  - Confronting superstitions

  - More monitoring and regulation and adopting stricter rules
- Verbal attacks:

  - Non-imposition of beliefs: If people impose their opinions on a person in the real world, with respect to freedom of speech the oppressed person may fight with these beliefs as verbal attacks.

  - Lack of bias: Excessive bias may cause abnormalities among people in cyberspace. Individuals in cyberspace must also respect each other’s ideas and avoid bias in their thoughts. “Whoever disagrees with your thoughts is not your enemy!”
- Online theft and Copyright violation:

  - Establishing state-specific rules: Unfortunately, in Iran, copyrights are not respected as they should. In this regard, the government must enforce strict rules and even take heavy fines from offenders.

  - Crimes shall be considered for sources that allow illegal downloading or other online thefts.

  - Cultural development; the necessary trainings are needed to raise the level of community culture in this field.
- Negative behavioral and personality impacts:

  - Families’ education and attention: Families’ education and attention to their children from childhood play an important role in reducing the negative effects of behavior and personality.

In general, it is recommended to promote awareness of ICT ethics among students and individuals. To achieve this, a moral framework must be created and developed. In addition, in order to promote ethics, universities, as well as schools, must actively develop ethical education in their curriculum to increase ethical awareness among students as the future representatives in the IT market.

Conclusion

In this study the ethical and social issues in the field of information technology is evaluated. Ethical issues in the field of information technology are ranked by the results of statistical analyses. According to the students’ opinion, anti-religious propaganda had the highest prevalence in cyberspace among the indices that With Informing people, teaching religious issues, more monitoring and determine the correct rules it can be reduced. Also hacking was also ranked in the last place. According to the conducted studies and the results obtained from this study, it can be concluded that ethics in information technology can be trained. Therefore, mandatory syllabus for students in bachelors and master and PhD course on ethical issues in information technology seems essential to cope with the ethical challenges of IT. Finally, a set of strategies and training for controlling unethical activities in the field of information technology was presented with the hope that their challenges are reduced.

VII. Future Research

As noted earlier, this study has studied public awareness of some ethical issues in information technology among students, but the age related issues have not been addressed. Further research can consider on cultural differences, the gender based conditions, intellectual property rights and also user privacy behaviors in social network.

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Smart Mobile Healthcare System based on WBSN and 5G

Farah Nasri
Laboratory of Electronics and Micro-Electronics (EµE)
FSM, University of Monastir
Monastir, Tunisia

Abdellatif Mtibaa
Laboratory of Electronics and Micro-Electronics (EµE)
ENIM, University of Monastir
Monastir, Tunisia

***Abstract*—The intelligent use of resources enabled by Internet of Things has raised the expectations of the technical as well as the consumer community. However there are many challenges in designing an IoT healthcare system, like security, authentication and exchanging data. The IoT healthcare system, is transforming everyday physical objects, medical devices that surround us into an embedded smart healthcare system. Public healthcare has been paid an increasing attention given the human population and medical expenses exponential growth. It is well known that an effective monitoring healthcare system can detect abnormalities of health conditions in time and make diagnoses according to sensing (WBSN) data. This paper propose a general architecture of a smart mobile IoT healthcare system for monitoring patients risk using a smart phone and 5G. The design of multi-protocol unit for universal connectivity. Web and mobile applications developed to meet the needs of patients, doctors, laboratories analysis and hospitals services. The system advises and alerts in real time the doctors/medical assistants about the changing of vital parameters of the patients, such as body temperature, pulse and Oxygen in Blood etc… and also about important changes on environmental parameters, in order to take preventive measures, save lives in critical care and emergency situations.**

Keywords—IoT; multi-protocol; smart mobile healthcare system; WBSN; android; 5G

I. Introduction

With a rapid growth of human population and medical expenditure, mobile IoT healthcare becomes one of most significant issues for both individuals and governments. Meanwhile, according to a report from the World Health Organization (WHO), the problem of population aging is becoming more serious. Health conditions of aged people usually need to be checked more frequently [1], which poses a greater challenge to existing medical systems [2]. Therefore, how to identify human diseases in time and accurate manner with low costs has been paid an increasing attention [3]-[5]. Moreover in science and technology industries, it has been observed that whenever a person is exposed to overwork, it mostly leads to fatigue. If this condition continues unattended this might lead to other complications such as heart diseases and sometimes even cause a major drop of oxygen level in the body. It eventually becomes fatal for that person. Likewise, a large number of workers who are exposed to aggressive environments die due to cardiovascular diseases every year. The present world population also has an increase in the number of aged people who seek health care. The majority of them lives alone or remains inside their home. Hence, in case of emergency situations, if the patients do not get the immediate medical care, the chances of death become high. Therefore a healthcare system for monitoring the vital signs of the human body would be a smart way to prevent such situations [6]. These vital signs which include body temperature, heart or pulse rate, respiration rate, blood pressure and oxygen saturation level, are measurements of the body's most basic functions which are useful in detecting or monitoring medical problems [7]-[9]. A specific IoT healthcare system fills in this gap by acting as multi-protocol platform between public network and local WBSN with specific needs. IoT is a network of connected Things with embedded system allowing them to sense, report, control remotely and sometimes take decisions. The concept of objects with electronics connected to a network has existed for quite a while now. While the premise of connection to the Internet increases reach of IoT [10]-[12], it also poses some challenges. First challenge is that many IoT nodes have limited memory, storage and computation capabilities and are not able to connect to the IP based networks directly. Second challenge is the universality of connection protocols.

This paper aims to provide measures of physiological parameters such as body temperature, pulse rate and oxygen saturation level. The physiological data are processed using 5G, body sensors coupled to an Arduino and RasberryPi boards. The mobile healthcare system (IoT platform) is designed to gather Biometric information. This information can be used to monitor in real time the state of a patient or to get sensitive data in order to be subsequently analyzed for medical diagnosis, using an android application, web services and multi-protocol unit. The design of specific multi-protocol unit for universal connectivity of WBSN. The smart mobile healthcare system advises and alerts in real time the doctors/medical assistants about the changing of vital parameters of the patients and about important changes in environmental parameters, in order to take preventive measures, save lives in critical care and emergency situations.

The remainder of this paper is organized as follows. Section 2 describes some related works, and Section 3 explains the architecture of a smart mobile healthcare system. Section 4 discusses specific multi-protocol unit for universal connectivity. Section 5 shows the transfer of the temperature, from body sensor to the android mobile interface. Section 6 present some Android interfaces for doctors, the system advises and alerts via Android interface in real time doctors/medical assistants about the changing of patient's vital parameters. Section 7 present the study of the existing system and the different use case diagrams, the class diagram contains attributes, methods, and associations of objects. Section 8 shows the web application developed to meet patients' and doctors' needs, analytical laboratories and hospitals. Finally, Section 7 draws some conclusions and discusses some possible directions for future research.

II. Related Work

Wireless body sensor network (WBSN) may engage different technologies at different levels [13]-[18]. So many issues of researches are then opened to be studied such as energy consumption, architecture, routing solution and communication protocols. In [19], the authors propose solutions to the energy minimization problem and network lifetime maximization problem based on intelligent time and power resource allocation in WBSN context. Both problems are formulated and solved as geometric programming. In [20], the authors propose a relay based routing protocol for Wireless in Body Sensor Network. Network lifetime maximization and end-to-end-delay problems are formulated and solved with linear programming. However, No systematic scheme is proposed to address the optimal relay location consideration.

Furthermore, since the model proposed considers only routing layer, it fails to formulate a cross-layer optimization problem. Considerations on other layers, such as power control technique, are neglected. In [21], the authors propose a mathematical optimization problem that jointly considers network topology design and cross-layer optimization in WBSNs.

For comparative purposes, many works are focused on the revision of each type of health sensor and the way of communication with the server or the other sensor. Wen-Tsai Sung et al. [22] proposed a measurement system which monitors the physical condition of the users. It helps them to maintain healthy physiological conditions. These three modules (ECG, blood pressure and oxygen saturation) will record the physiological signals and then send the data to a mobile device. The system focuses upon three communication system for data transmission (RS-232, ZigBee, and Bluetooth). The data is viewed on an Android mobile device and then immediately sent to the cloud server through Internet. RenGuey Lee, et al. [23] proposed a system to prevent and control the physiological parameters affected by both chronic diseases: hypertension and arrhythmia. The system is a role-based smart mobile care system with alert mechanism. Each of these persons uses a mobile phone device to communicate with the server setup. This system uses physiological signal recognition algorithms in commercial mobile phones with Bluetooth communication capability. William Walker, et al. [24] proposed a system to monitor the blood pressure of a patient. The data has been transferred to a monitoring center using wireless sensor network. The data is displayed and stored there. The Blood Pressure data acquisition module is interfaced with a user-friendly graphical user interface. It monitors current and past measurements for all patients through wireless transmission. Zhe Yang et al. [25] propose an architecture of an ECG monitoring system based on the Internet of Things cloud. The ECG data gathered from the human body is transmitted directly to the IoT cloud using Wi-Fi.

In conclusion there are many ways to communicate with the sensors such wired link, Bluetooth, ZigBee, Wi-Fi… This paper propose to unify most of them into one specific multi-protocol unit for universal connectivity.

III. Architecture of a Mobile Healthcare System

The basic functions of a smart healthcare application include ECG waveform and display pulse and oxygen in blood [26], body temperature [27], [28], etc. Also through smart phone screen or printed paper media, indication as well as simple user interface through buttons.

More features, such as patient record storage through convenient media, multiple levels of diagnostic capabilities are also assisting doctors and people without specific trainings to understand how to use smart IoT healthcare application and their indications conditions.

Smart wireless body sensors networks are applications that measure Pulse and Oxygen in Blood. Results can be saved for future reference and track of multiple people with individual profiles can be kept, (see Fig. 1). This application has access to the following:

Wireless network communication, Full network access, allows the application to create network sockets and use custom network protocols. The android interface receives data from WBSN through Wi-Fi, ZigBee or Bluetooth, so this permission is required to send data through the Web.

The access to Bluetooth, ZigBee or Wi-Fi settings, allows the application to configure the local device, and to discover remote devices. Network allows the application to view information about network connections such as which networks is connected.

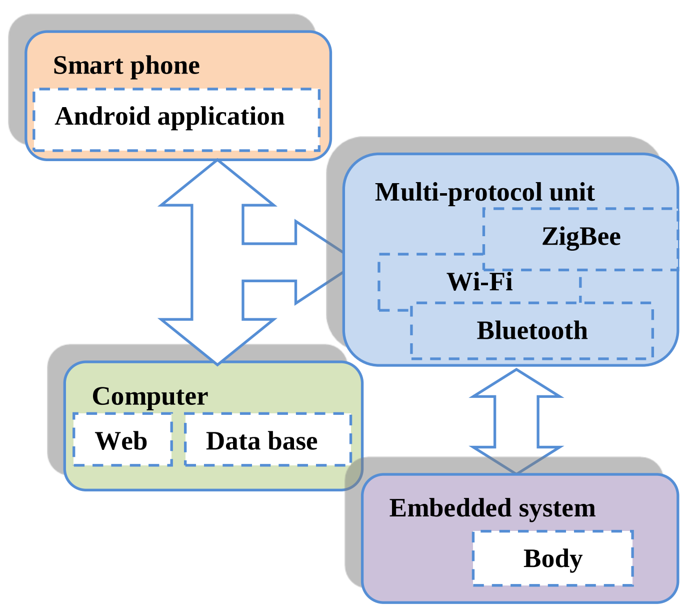

Fig. 1. Architecture of smart mobile healthcare system.

A. Specification of Requirements

It is essential to understand the stakes and the needs of the users to arrive at an adapted computer tool in the time allowed. This is the specification of the services offered to the users and provided by the system to be designed. Within this framework, two types of needs are to be studied:

- Functional requirements.
- Non-functional requirements.

Beginning by identifying the actors of our application afterwards making clear the functionalities offered to the users.

B. Identification of Actors

The actor represents the external entity that acts on the system (operator, other system ...). It can view or change the system status. In response to the action of an actor, the system provides a service that corresponds to its need.

- The doctor: It is the one who does the registration in the web application to manage his patients and to monitor remotely each one.
- The Patient: It is the Smartphone user who wants to use the mobile application in order to contact his doctor and send him the results of the medical analysis performed.

C. Specification of Functional Requirements

Functional needs or business needs represent the actions that the system must perform; it only becomes operational if it satisfies them. They express an action that the system must perform in response to a request (see Fig. 2). These are the functions, operations or transformations that the application must perform. Our application should mainly cover the functional requirements shown in the following table (Table 1).

TABLE I. FUNCTIONAL REQUIREMENTS

Actor	Functionalities
Doctor	• Authentication Management. • Profile Management. • Patients Management. • Messages Management. • Notifications Management. • Appointments Management. • Medical analysis Management and monitoring of patient. • Medical prescription Management.
Patient	• Authentication Management. • Profile Management. • Subscription Management. • Messages Management. • Medical analysis Management.

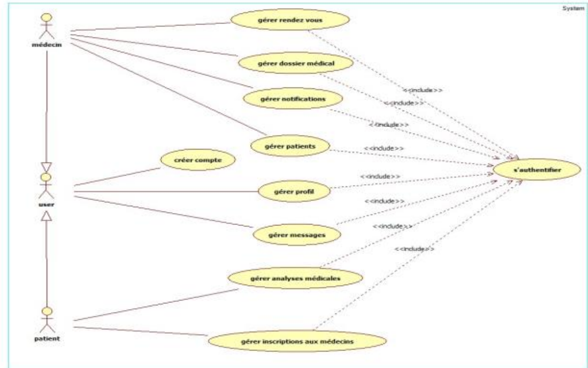

Fig. 2. Case diagram use.

IV. SPECIFIC MULTI-PROTOCOL UNIT FOR UNIVERSAL CONNECTIVITY

Connectivity is essential in any networked system. If the application is highly distributed, more than one type of protocols may be used. Such as one could use Wi-Fi or ZigBee for local network communication and use 4G or 5G for wide area communication [20]. The main function of this link is to transfer the information gathered and processed by the end node to the application software or based service. Connectivity is always in duplex form. It acts for communication between application software and local hardware. Bluetooth, Wi-Fi, ZigBee, etc. are types of local connectivity used for house or office automation projects. GSM, 4G, 5G and RF are other types of connectivity used for long range communication. Some of the Bluetooth, GSM or RF modules are readily available in marketplace. The rest of the complex modules need to be built specifically depending on the application complexity.

A. Multi-Protocol Unit Designed for the IoT Platform

In general, each unit should carry out the following steps:

- Wait for and detect connected devices.
- Determine the device's accessory mode support.
- Attempt to start the device in accessory mode if needed.
- Establish communication with the device if it supports the Android accessory protocol.

1) ZigBee module: The ZigBee protocol was developed with low-cost, low-power consumption, two ways wireless communications standard. Solutions adopting ZigBee standard are embedded in consumer electronics, PC peripherals, and medical sensor applications.

2) Bluetooth module: The functional requirement for Bluetooth networking encapsulation protocol includes the following, support for common networking protocols such as IPv4, IPv6, IPX, and other existing or emerging network protocols as defined by the Network protocol types. Many protocols are used for various computing devices together. Although IPv4 and IPv6 are perceived as the most important networking protocols, it is a requirement that Bluetooth Networking is able to support other popular protocols Low Overhead.

3) Wi-Fi module: Wi-Fi is a new technology defined by the Wi-Fi Alliance aiming to enhance direct device to device communications.

Thus, given the wide base of devices with Wi-Fi capabilities, and the fact that it can be entirely implemented in software over traditional Wi-Fi radios; this technology is expected to have a significant impact.

To connect several sensors on the same platform using different protocols, one has to think about the conversion of the protocol. Then designing and developing an HTML interface for multi-protocol exchanger. The HTML interface (Fig. 3) showed the desire choice of exchange protocols:

- Wi-Fi to Bluetooth
- Ethernet to Bluetooth
- Ethernet to Wi-Fi
- ZigBee to Bluetooth
- ZigBee to Wi-Fi

Fig. 4 shows the data transfer between the HTML interface and the hardware part. Using an Arduino board coupled with several modules such as Wi-Fi, ZigBee, and Bluetooth. The Arduino board is programmed using C Language.

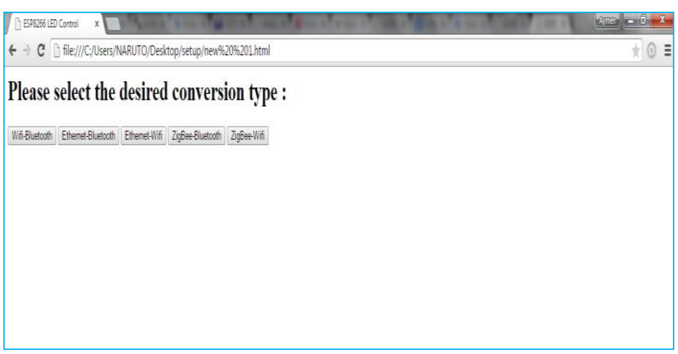

Fig. 3. HTML interface of specific multi-protocol unit for universal connectivity.

Fig. 4. Pulse and oxygen in blood sensor (SPO2).

V. WBSN for Monitoring Parameters of IOT Healthcare System

The IoT technology is a very important key in Wireless Body Sensor Network (WBSN) [29]. It connects a set of sensors into a network through wireless communication system. The sensor nodes are normally lightweight, inexpensive, easy to deploy and maintain, but the capability and functionality are limited by resources (sensors, processors, memories, energy sources, etc.) [30]. Specific multi-protocol unit, web and mobile applications, are emphasized in the design of our IoT platform for healthcare.

The sensors can be used for collecting and transmitting information about their surrounding environment using android interfaces and web.

The data is sent through Wi-Fi, ZigBee or Bluetooth independently of protocol used by the sensor.

Pulse oximetry a noninvasive method of indicating the arterial oxygen saturation of functional hemoglobin. Oxygen saturation is defined as the measurement of the amount of oxygen dissolved in blood, based on the detection of Hemoglobin and Deoxyhemoglobin. Two different light wavelengths are used to measure the actual difference in the absorption spectra of HbO2 and Hb. The bloodstream is affected by the concentration of HbO2 and Hb, and their absorption coefficients are measured using two wavelengths 660 nm (red light spectra) and 940 nm (infrared light spectra). Deoxygenated and oxygenated hemoglobin absorb different wavelengths. Fig. 5 shows the data transfer (Pulse=98cpm, Oxygen=88%, in blood) from sensor to the android interface.

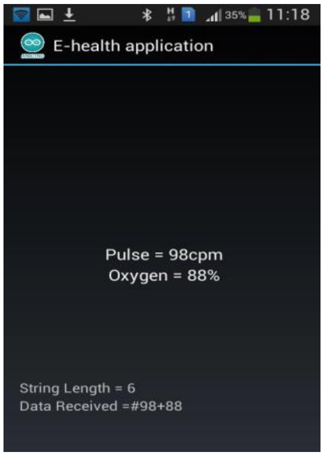

Fig. 5. Android interface: data receiving.

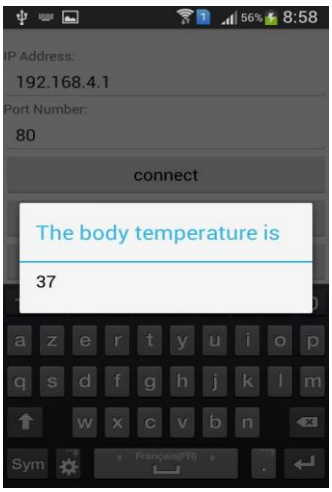

Fig. 6. Android interface: body temperature.

This sensor allows measuring the body temperature. It is of great medical importance to measure body temperature. The reason is that a number of diseases are accompanied by characteristic changes in body temperature. Likewise, the course of certain diseases can be monitored by measuring body temperature, and the efficiency of a treatment initiated can be evaluated by the physician. The transfer of the temperature, from body sensor to the android mobile interface is given in Fig. 6.

All data are transferred in real time to the doctor in two ways: a mobile or web interfaces.

VI. Android Interfaces

Android allows implementing device specifications and drivers. The hardware abstraction layer (HAL) provides a standard method for creating software hooks between the Android platform stack and hardware. The Android operating system is also an open source, to develop interfaces and enhancements. To ensure devices maintaining a high level of quality and offering a consistent user experience, each device must pass tests in the compatibility test suite (CTS). The CTS verifies devices to meet a quality standard that ensures running applications reliably. Users have easily a good experience for details on the CTS. Internet of Things based on Communication Technologies play a significant role in Healthcare systems and has contribution in development of medical information systems.

The development of IoT platforms using android applications ensures and increases the patient's safety and the quality of life and other healthcare activities. The tracking, tracing and monitoring of patients and healthcare actors activities are challenging research activities. The system advises and alerts via Android interface in real time doctors/medical assistants about the changing of vital parameters or the movement of the patients and also about important changes in environmental parameters, in order to take preventive measures.

In the experimental IoT platform, two main actors are used: patients and doctors.

A. Android Unit for Doctors

This section present some Android interfaces for doctors. Fig. 7 shows the registration and the doctor desk. The doctor can make a registration or unsubscribe freely.

For more account security of the doctors, each one should have a code (see Fig. 8).

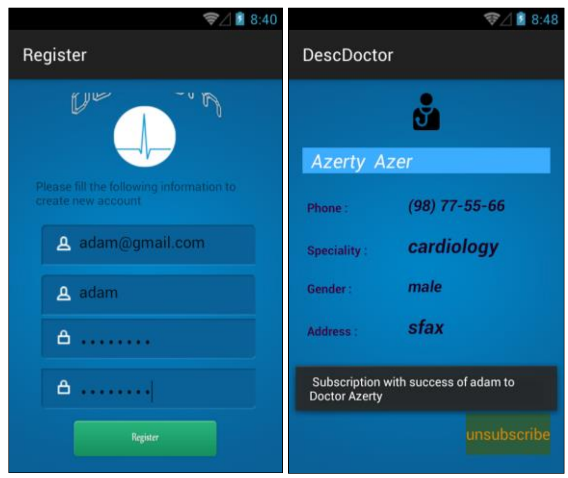

Fig. 7. Register and doctor desk access.

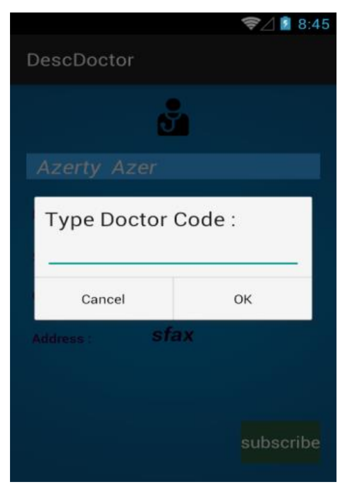

Fig. 8. Doctor typing a code.

B. Android Unit for Patient

For proper platform operations, it's necessary to develop some android interfaces, as mentioned in Fig. 9 to 12. In effect the patient can make a registration (Fig. 9) and after the authentication a window of the main menu opens (Fig. 10). The main menu contains several choices:

- View Profile: For updating profile.
- Doctors List: To see the list of doctors in the various services.
- New Exam: To receive the list of new exams given by his doctor.
- Medical Exams: History of analyzes and medical prescriptions.

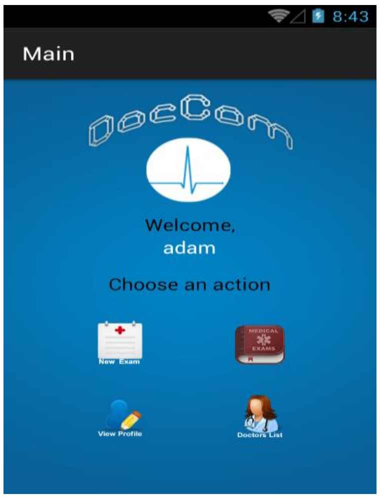

Fig. 9. Patient main menu.

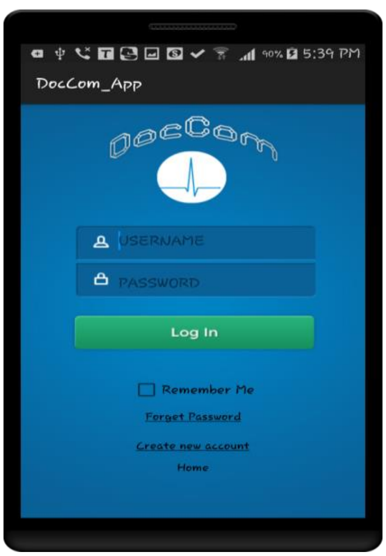

Fig. 10. Patient authentication.

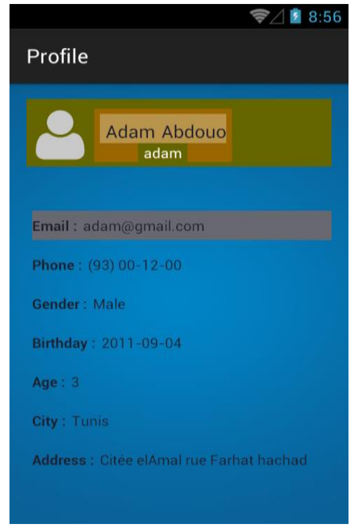

Fig. 11. Patient profile.

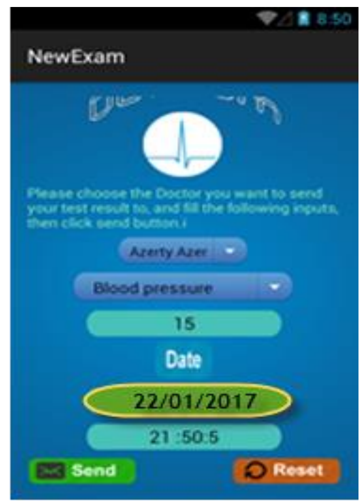

Fig. 12. Patient send medical test.

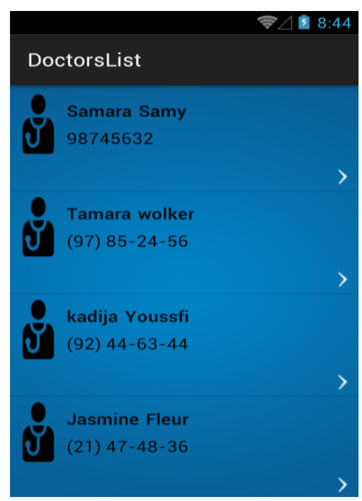

Fig. 13. Doctors list.

The patient can see his profile, choose his doctor and send medical test (Fig. 12 and 13).

VII. Static Aspect: Class Diagram

Class diagrams are UML diagrams used to model the entities (classes) involved in the system as well as the different relationships between them. The class diagram contains attributes, methods, and associations of objects. Indeed, an object is an identifiable entity that may have a physical existence (a person) or not have it (message). Each object has a set of attributes (object structure) and a set of methods (object behavior). A set of similar objects (having the same structure and behavior) forms a class of objects. Attributes and methods can then be defined in common at the class level. Obviously, classes in RAM are often linked to persistent data (stored in database, in files, in directories, etc.).

Based on the study of the existing system and the different use case diagrams, have been able to identify the main classes illustrated in Fig. 14 for a clearer view of the system under study. From this diagram, the entities of the corresponding database are cleared in the application to be developed.

VIII. Web Application

There are many communication protocols which can be used by the IoT healthcare to communicate with the web and mobile applications. Here discussion some of the popular technologies along with their pros and cons.

Plain HTTP: This is by far the most ubiquitous protocol. It's widely accepted by servers and being backed by Internet standards, has least compatibility issues. It also maps naturally with the RESTful APIs. However it suffers from large overhead in form of HTTP headers and text based format. It is stateless despite being run on top of TCP. That makes it unsuitable for real-time usage. The client must send a request in order to get a response (command) from the server. Client has to keep polling for updates from the server.

CoAP: Constrained Application Protocol can be considered to be binary version of HTTP. It improves on some limitations on HTTP. It has very concise headers and supported binary data format thus reducing the overhead. It can be used on top of TCP or other transport as well even SMS. CoAP packets can be easily translated to a HTTP packet. However because of negligible Internet infrastructure support it does not run well with firewalls, proxies and routers. Thus this protocol is only suitable for private networks typically inside the sensor network.

Web Sockets: It is a new protocol also backed by web standards. It has the same addressing and handshake mechanism as used by HTTP, thus making it compatible with existing network infrastructure. Once handshake is complete it switches to duplex communication on top of TCP. This makes it suitable for real time, two way communication. It's especially suited in shared hosting environments and gateways operating behind proxies.

MQTT: Is also a popular protocol running (optionally) on top of TCP. It has a topic subscriber model. Though more suited for broadcasting messages to interested gateways, it's also used for gateway to server communication. It has some features like last message persistence and will and testament message that make it useful for IoT application.

AMQP: This perhaps is the most suited protocol for gateway server communication. This protocol acts as a storing queue and ensures that packets are not lost, even in case of temporary outage.

XMPP: Extensible Messaging and Presence Protocol is a popular protocol used by chat clients for real time communication. It standardizes lot of things like user authentication and message IDs. However owing to its complex specification and exchange of data using verbose XML format makes it suitable for IoT applications.

Here the flexible design for sensor data monitoring and control is presented. The application is a generic one without special requirements for security or reliability. The goal of this application is to replace a traditional and manual system with an intelligent computing solution that allows physicians to manage patients and their medical records by replacing conventional medical records on paper with computerized medical records and on the other hand allowing patients to follow their doctors and update them about their state of health (Fig. 12).

The web Application called DocCom offers security for every doctor, in fact everyone must make a registration in his domain of specialty (see Fig. 15).

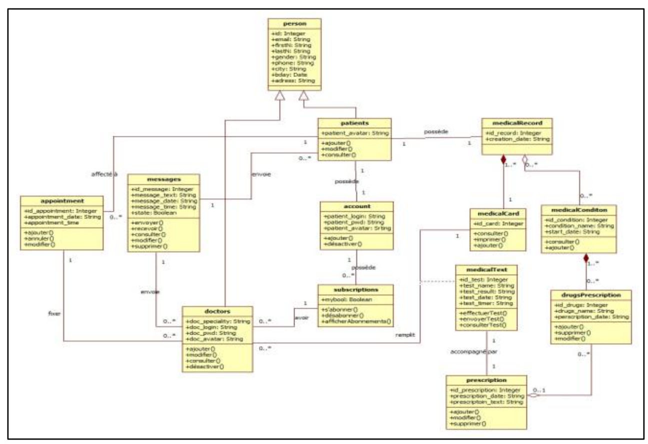

Fig. 14. General class diagram.

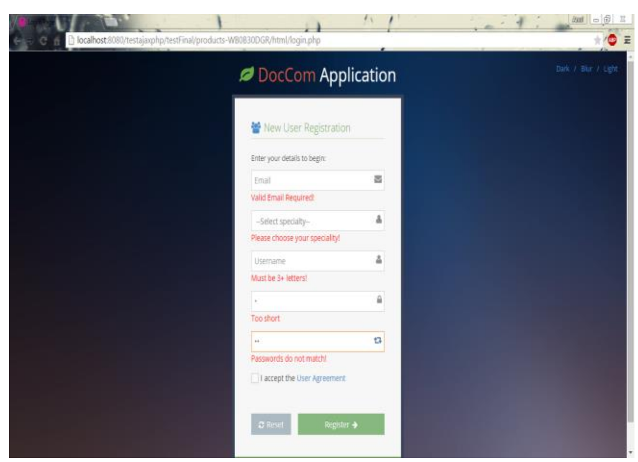

Fig. 15. Registration interface.

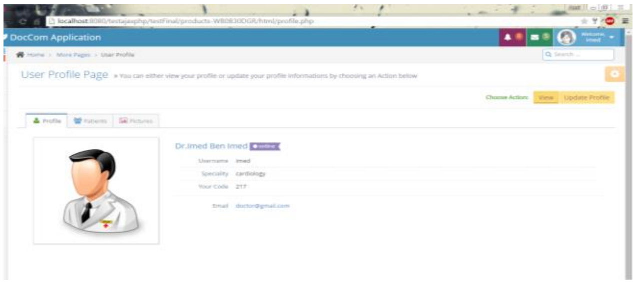

Fig. 16. Medical consultation interface.

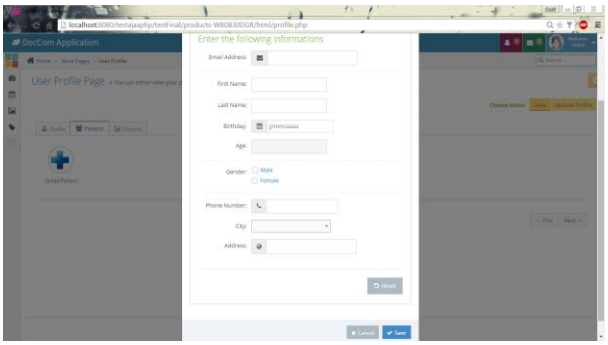

Fig. 17. Adding new patient.

As you can see in DocCom application (Fig. 16) the Doctor profile contains the following headings:

- User name,
- Specialty,
- Security code.

Doctor can either view profile or update profile information by choosing an action. At the top right of the interface you can see two icon the first for notification and alert in real time and the second for emails.

The doctor can add a new patient by entering the following information (Fig. 17):

- Email address,
- First name,
- Last name,
- Birthday,
- Gender,
- Phone number,
- City and Address.

Patient management is done using the notification as shown in Fig. 18. The doctor can directly see the notification of each patient and respond. By mail the doctor can receive medical analysis tests sent by the patient or by the laboratory of medical analysis. The doctor may send a medical prescription or a medical analysis test for each patient. In case of emergency the doctor can send an alert to a nearest medical center.

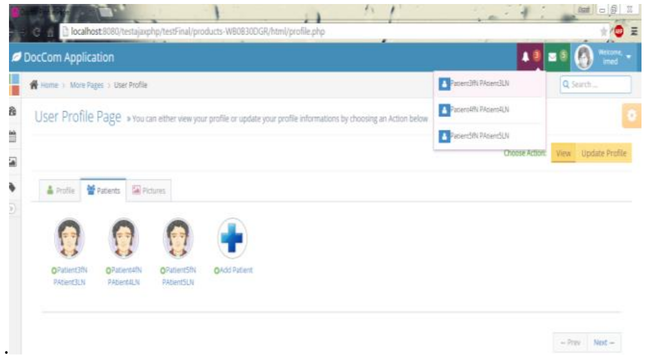

Fig. 18. List of patients registered for this doctor.

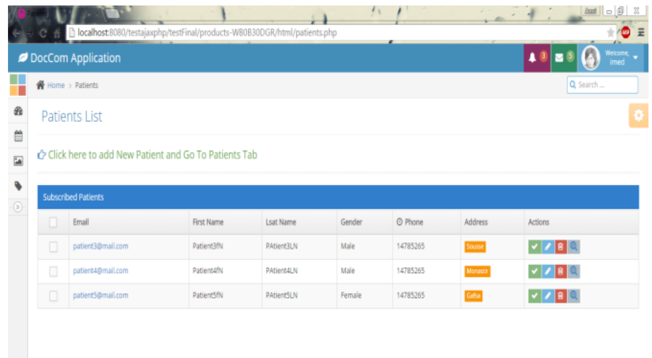

Fig. 19. Patients management for doctor.

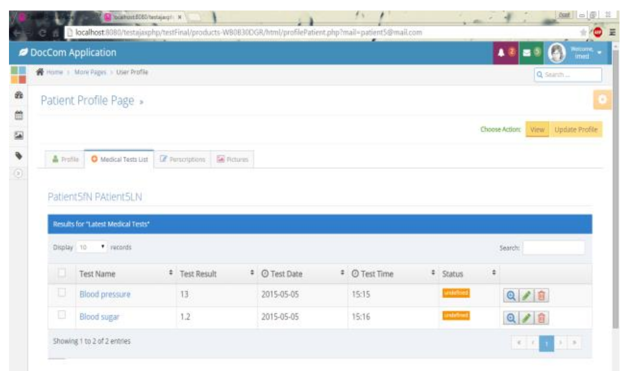

Fig. 20. Medical consultation management: medical tests sent by the patient.

The above interface shows the list of patients for each doctor, of course he may do the necessary acts for each patient. The doctor can see the historical of medical tests and historical of medical prescriptions for each patient.

DocCom (Fig. 15 to 20) is the web application developed to meet patients' and doctors' needs, analytical laboratories and hospitals. Each user can create an account, the patient send medical analysis to the doctor via DocCom mobile application, the doctor answers by a medical prescription or by an appointment at the hospital. In the critical case of a patient, his doctor receives an alert on his smart phone and on the web application DocCom, so the doctor can do the necessary actions.

IX. Conclusions

The smart IoT for healthcare system has been designed. It aims to help patients to consult anywhere doctors, and doctors to follow up patient's requests and data. It uses Wireless Body Sensor and information technologies to provide remotely clinical healthcare. It helps to reduce distance barriers and improve access to medical services. It is also used to save lives in critical care and emergency situations inside cities and rural communities.

A mobile application allows:

- The patient to connect via IoT platform.
- Sensing the health parameters.
- Contacting the doctor.
- Sending in real time and easily the results of performed medical tests.
- Following the medical record.

The physician doctor manages patient's consultations and remote follow-up.

Today's 4G and 5G networks use the latest technologies and continue to offer faster data access. The mobile Internet inspires researchers to meet faster data transmission with greater capacity.

Mobile healthcare application concepts have been developed over many years and some have become widely used. It is very important for doctors and patients to be in touch in real time through the same cloud plate form. Healthcare can be improved when reducing time of communication and diagnosis.

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A Genetic Algorithm for Optimizing TCM Encoder

Rekkal Kahina
LTIT Laboratory
Tahri Mohammed University-Bechar
Street independence B.P 417
Bechar, Algeria

Abdesselam Bassou
Department of Electrical Engineering, Faculty of Technology,
Tahri Mohammed University-Bechar
Street independence B.P 417

***Abstract*—This article describes a genetic algorithm for the optimization of the Trellis Coded Modulation (TCM) schemes with a view to achieve a higher performance in the multipath fading channel. The use of genetic algorithms is motivated by the fact that they are capable of performing global searches to retrieve an approximate solution to an optimization problem and if the solution is unknown to provide one within a reasonable time lapse. The TCM schemes are indeed optimized by the Rouane and Costello algorithm but the latter has as major disadvantage high requirements in both computation time and memory storage. This is further exacerbated by an increase in the encoder rate, the number of memory piles and the depth of the trellis. We describe a genetic algorithm which is especially well suited to combinatorial optimization, in particular to the optimization of NP-complete problems for which the computation time grows with the complexity of the problem, in a non-polynomial way. Furthermore this opens up the possibility of using the method for the generation of codes for channel characteristics for which no optimization codes are yet known. Simulation results are presented, that show the evolutionary programming algorithm on several generations of populations which only exhibit a medium probability of exchanging genetic information.**

***Keywords*—Trellis Coded Modulation; free distance; genetic algorithm**

I. Introduction

Multilevel modulation of convolutionally encoded symbols was a technique known before the introduction of TCM. The innovative aspect of TCM is the idea that convolutional encoding and modulation should be treated as a unique operation and not as separate entities [1].

As a result, instead of first demodulating and then decoding the received signal, the demodulation and decoding are combined, by the receiver, in a single process. Consequently, the parameter governing the performance of the transmission system is no longer the free Hamming distance of the convolutional code, but becomes the free Euclidean distance between transmitted signal sequences, over the additive white Gaussian noise channel. Thus the optimization of the TCM design will be based on Euclidean distances rather than on Hamming distances, so that the choice of the code and of the signal constellation will not be performed separately. To this end, much research has been done to optimize TCM encoder schemes by maximizing the free distance as is the case in Rouane and Costello's work [2] which defines an algorithm aiming to maximize the free distance which computes the spectrum of linear, regular and quasi-regular trellis codes.

This optimization has not only affected the design of TCM schemes but has also affected the points of constellations where Matthew C Valenti [3] had described a genetic algorithm for solving the symbol labelling problem and extending the algorithm to optimize their location in the signal space. Yang [4] describes a search method, based on genetic algorithms, to solve the problem of the signal constellations mapping which minimizes the BER of the system. In [5] Confessore describes a genetic algorithm to design satellite constellations for regional coverage. The performance was tested by evaluating optimal satellite configurations both for global coverage and for regional coverage and an extensive series of computational tests was performed to validate the meta-heuristic approach proposed for regional coverage. Tania [6] made use of a genetic algorithm to maximize the percent coverage and minimize the revisit time for a small satellite constellation with limited coverage. Anit Kumar [7] studied the encoding in genetic algorithms which is essentially dependent on the type of problem and examined different coding schemes according to the problems in which they are used.

In fact, genetic algorithms are used by large companies to optimize schedules and design products which can range from large aircrafts to tiny computer chips or to medicines [8]. They thus make use of the power and efficacy of genetic algorithms which are able to find solutions to problems that other optimization methods cannot handle because of a lack of continuity, derivatives, linearity, or other features. Our work aims to optimize the TCM scheme for which we propose a genetic algorithm to design and optimize the placement of branches which are used for the systematic and parity bits and the connectivity of the memories between them. By letting the design evolve over several generations, new encoder formats are found with lower binary error levels than had previously been obtained by applying one of the two modulation techniques QAM or PSK depending on the choice of encoder rate.

The remainder of the paper is organized as follows: Section II provides a model of the system under consideration. Section III provides the simulation results with a comparison of the initial and second population; the best code generated by the genetic algorithm as compared to the Ungerboeck code in the cases of three, four and five memories. Section IV concludes the paper.

II. System Model

Genetic algorithms are a type of optimization algorithm used to find the optimal solution(s) to a given computational problem that maximizes or minimizes a particular function. In this article, our goal is to maximize the free distance using a genetic algorithm. Before giving the fitness function, we will first provide a definition of free distance.

A. Definition of Free Distance (d_{free})

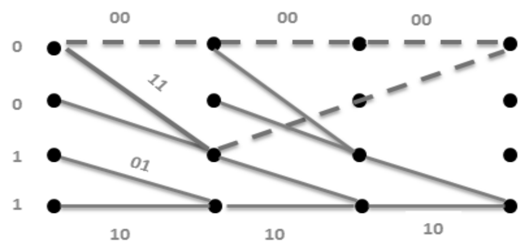


Fig. 1. Two pairs of paths diverging at time n = 0 and reaching the same states at the same time.

Free distance represents the shortest distance between two divergent paths starting from the same point (state) and returning to that point as quickly as possible as shown in Fig.1. This distance represents the distance between two nearest paths without error.

B. Design of the TCM Encoder

The generic TCM encoder, proposed by Ungerboeck [1], is presented in Fig. 2. It allows the generation from m input bits (within the input symbol u_n), an output that contains the m systematic bits and a parity bit produced using a combination of the m input bits and the last state of the encoder memory of size v that yields a coding rate R = $\frac{m}{m+1}$. The design of a TCM encoder consists in the determination of the parameters h_{ij}, $i \in \{0,1,..,m\}$ and $j \in \{0,1,....v\}$, which can take values from$\{0,1\}$. The TCM encoder, presented in (2), imposes the following assumption: $h_{00} = h_{0v} = 1$ and $h_{i0} = h_{iv} = 0, i \in \{1,..,m\}$.

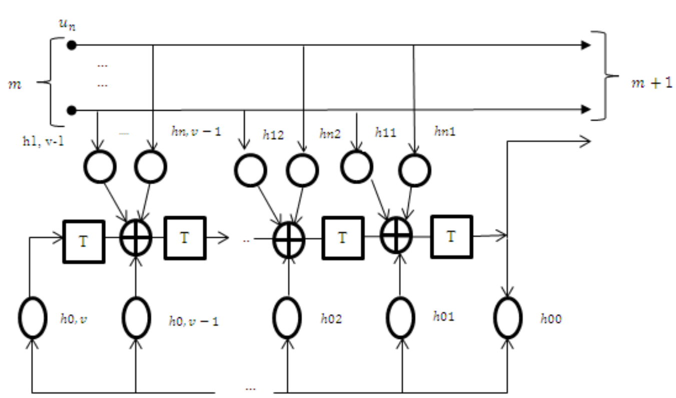


Fig. 2. Generic TCM encoder [1].

The TCM encoder can be represented, using the parameters h_{ij}. by polynomials $H_i(D)$ of the variable D as follows: $H_i(D) = \sum_{j=0}^{v} h_{ij} \cdot D^j$, $i \in \{0, ..., m\}$, or by the code generator $(h_0, h_1, ..., h_m)$ written in octal [9].

Let G be a $v \times v$ matrix which describes how the state variables at time n+l are related to the state variables at time n, and let T be a $v \times m$ matrix which describes how the symbols at time n+l depend on the input symbol at time n. Using these relationships, the future state (S_{n+l}) of the encoder in Fig. 2 can be constructed as follows:

$$S_{n+1} = G.S_n + T.u_n \quad (1)$$

Where, u_n is a $m \times 1$ vector describing the current input, and S_n is a $v\ x\ 1$ vector describing the current state.

Equation (1) can be expressed as a polynomial using D-transform as in [10].

$$S(D) = (I.D + G)^{-1}T \cdot x(D) \quad (2)$$

- Example on TCM encoder.

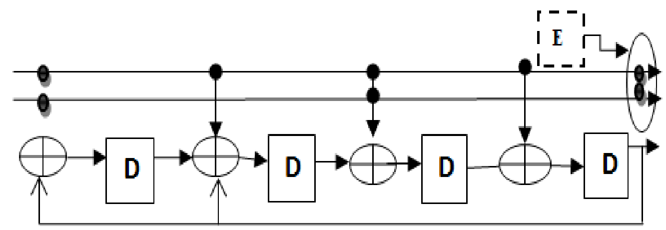


Fig. 3. Example of a 16-state TCM encoder [1].

Consider the 16-state rate 2/3 TCM encoder shown in Fig. 3 where "⊕" represents the operation of XOR and "D" represents the memory or the shift register of the TCM encoder.

The TCM encoder in Fig. 3 has three polynomials expressed as:

$$H_0(D) = D^4 + D + 1$$

$$H_1(D) = D^2$$

$$H_2(D) = D^3 + D^2 + D$$

and, the code generator is ($h_0 = 10011_2 = 23_8$, h1 = $00100_2 = 04_8$, $h_2 = 01110_2 = 16_8$), or in shorthand (23, 04, 16).

The matrix representation of this encoder configuration is given by

$$G = \begin{matrix} 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{matrix} \quad \text{and} \quad T = \begin{matrix} 0 & 0 \\ 1 & 0 \\ 1 & 1 \\ 1 & 0 \end{matrix} \quad \text{and } E = 0 \quad 0$$

C. TCM Encoder Representation using a Genetic Algorithm

Fig. 4 represents the TCM encoder with rate 2/3 comprising three branches, two of which represent the systematic bits and one represents the parity bit. "⊕" represents the operation of XOR and "D" represents the TCM encoder memory.

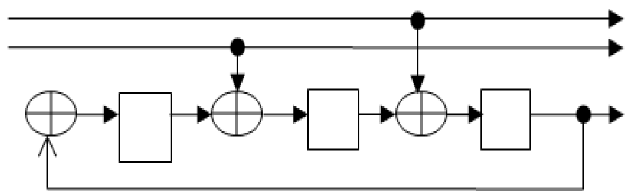


Fig. 4. Example of an 8-state TCM encoder [1].

The TCM encoder in Fig. 4 has three polynomials expressed as: h0 (D) = D^3+1; h1 (D) =D; h2 (D) = D^2, and the generator code is (h0 = $(1001)_2 = (11)_8$, h1 = $(0010)_2 = (02)_8$, h2 = $(0100)_2 = (04)_8$.

The matrix representation of this encoder configuration is as follows:

$$G = \begin{matrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{matrix} \quad , \quad T = \begin{matrix} 0 & 0 \\ 0 & 1 \\ 1 & 0 \end{matrix} \text{ and the output of the encoder}$$

E = [0 0].

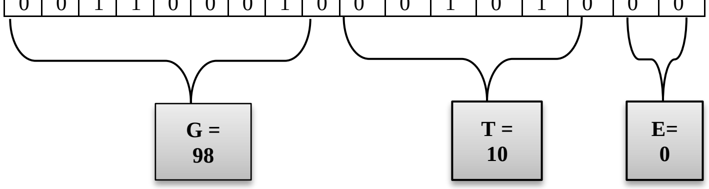
D. Binary Coding of the TCM Chromosome

The term chromosome refers to a numerical value or values that represent a candidate solution to the problem that the genetic algorithm is trying to solve [11]. Each candidate solution is encoded as an array of parameter values, where the performance of a genetic algorithm depends highly on the method used to encode this candidate solution into chromosomes and on what the fitness function is actually measuring [12].

In our work we represent the TCM encoder as an array with binary values which represent the three variables matrix G, T, E Where G = $[001100010]_2 = [98]_{10}$, T = $[001010]_2 = [10]_{10}$, E = $[0\ 0]_2 = 0$.

TABLE I. CHROMOSOME OF THE TCM ENCODER

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
0	0	1	1	0	0	0	1	0	0	0	1	0	1	0	0	0



- The size of the chromosome in Table 1 is equal to 17 bits in the case of three (3) memories, 26 bits in the case of four (4) memories and 37 bits in the case of five (5) memories.
- Some data is handed down by the parents, from one generation to the next. These are the hereditary genes. In our case to keep the same characteristics as for a recursive convolutional encoder the following cell indexes remain unchanged (Table 2) and are inherited by all the new generations of the TCM chromosome.

TABLE II. CELLS INHERITED FROM THE FATHER

3	4	5	7	8
1	1	0	0	1

In this paper, we work on recursive systematic code where matrix G represents the connectivity of the memories between them. In matrix G, value 1 (first row, last column) is set in position G [1, m], which makes the encoder recursive. Matrix G can be represented by 4 possible cases, as follows:

$$G = \begin{matrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{matrix} \text{ or } = \begin{matrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 1 \end{matrix} \text{ or } = \begin{matrix} 0 & 0 & 1 \\ 1 & 0 & 1 \\ 0 & 1 & 0 \end{matrix} \text{ or } = \begin{matrix} 0 & 0 & 1 \\ 1 & 0 & 1 \\ 0 & 1 & 1 \end{matrix}$$

In the case of matrix "T", as shown in Fig. 5, there are six (6) possible connexions. The number of possible cases for matrix "T" is equal to $2^{(Ne*m)}$ where "Ne" represents the number of bit per symbol and "m" represents the number of memories.

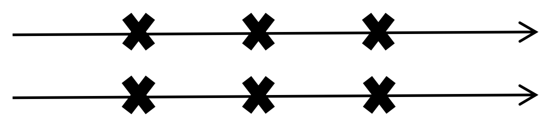


Fig. 5. Branches of systematic bits with six (06) possible connexions.

Finally, vector E represents the output of the TCM encoder, where the output of the encoder takes four candidates as follows: E = [0 0] or [0 1] or [1 0] or [1 1].

E. Reproduction of the TCM Encoder Operations using the Genetic Algorithm

Genetic algorithms can be applied to any process control application for the optimization of different parameters. Genetic algorithms use various operators viz. crossover, mutation for the proper selection of an optimized value. The selection of the appropriate crossover and mutation technique will depend on the encoding method and the problem requirement [13].

- Crossover: Applies to two different individuals where the result is:
  - Chromosome formed from the genes of its two parents.
  - Two children are "produced" for the next generation.
  - The decrement percentage is fixed.

A parent 1:

0	0	1	1	0	0		1	0	0	0	1	0	1		0	0

A parent 2:

0	0	1	1	0	1	1	1	0	0	0	1	0	1	1	0	1

Child 1:

0	0	1	1	0	0	1	1	0	0	0	1	0	1	1	0	0

Child 2:

0	0	1	1	0	1	0	1	0	0	0	1	0	1	0	0	0

- Mutation: Applies to a single individual by modifying one or more genes of the selected parent(s), where the result is:
  - ➢ A single new child is produced.
  - ➢ A mutation percentage is fixed.

A parent 1:

0	0	1	1	0	0	0	1	0	0	0	1	0	1	0	0	0

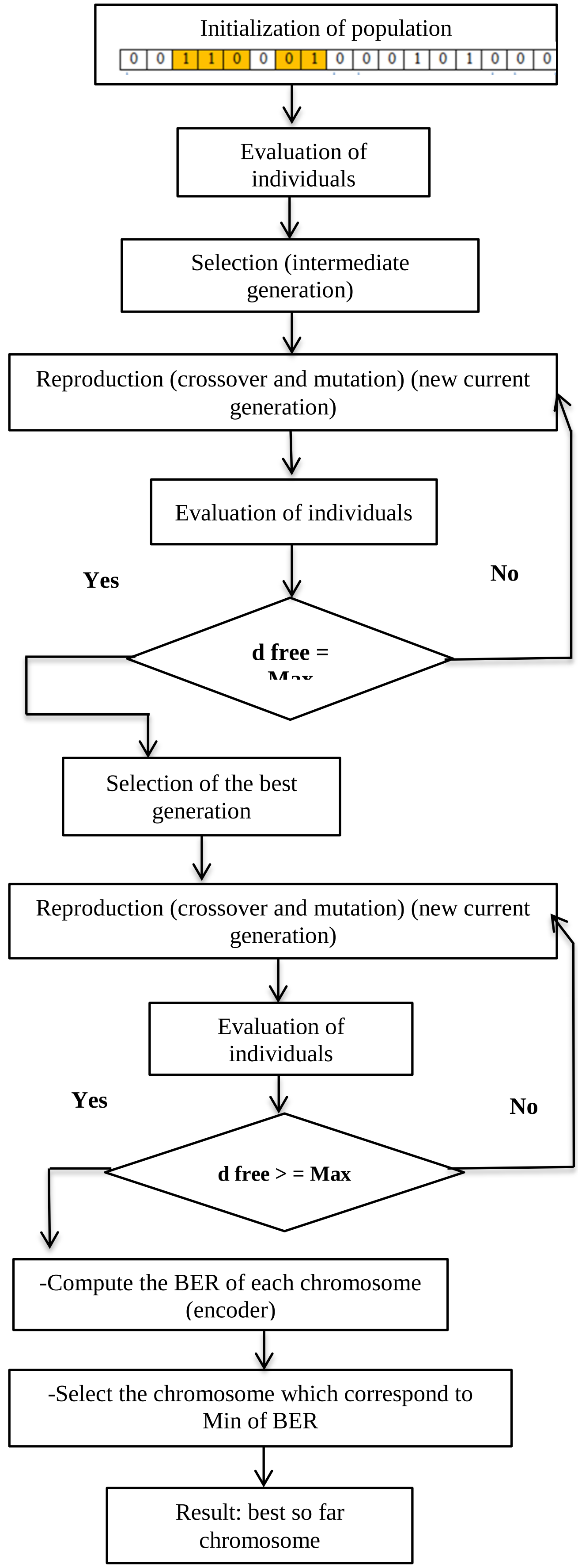
Child 1:

0	0	1	1	0	1	0	1	1	0	1	1	0	1	0	0	0

- Choose the selection method with the following three main objectives:
  - ➢ Choice of individuals which apply the reproduction operations for the creation of future generations (creation of a mating-pool).
  - ➢ "Selection" of the best individuals.
  - ➢ Possibility of exploring the different parts of the research setting.

F. Flowchart of the Genetic Algorithm for the TCM Scheme Optimization

Genetic algorithms begin with a set of solutions represented by chromosomes, called a population. Solutions from one population are taken and used to form a new population, which is motivated by the possibility that the new population will be better than the old one. Furthermore, solutions are selected according to their fitness to form new solutions, i.e. offsprings. The above process is repeated until some given condition is satisfied. The basic genetic algorithm is outlined as below:



III. Simulation Results

In this work, the genetic algorithm used to optimize the TCM encoder, based on maximizing the free distance of quasi-regular trellis code with three variables (G, T, E) in the interval [0, 5] where the fitness function is:

$$\text{Max } [F = \text{MyGa (fitness, G, T, E)}]$$

The algorithm is initialized with a population of 15 chromosomes. The encoder functions are indexed in increasing order so that the encoder is the best when its fitness function is equal to the maximum value and when the BER of the encoder is equal to the minimum value. Whenever the population changes, it is reindexed.

The genetic algorithm was run to optimize the encoder with three variables M = {G, T, E}, the population N = 15; the mutation rate $\Gamma = 0.03$, and the culling period Tc = M. The number of mutants δ per child was variable.

Initially, $\delta = 0$. If after Tc generations a new best encoder has not been identified, then δ is incremented up to a maximum of 30. On the other hand, if a new encoder has been identified within Tc generations, then δ is decremented.

The final value of d free (f(x)) is shown in Tables 3 and 4, the optimal generation which identified the best encoder is listed in Table 6.

Table 5 indicates the d free values obtained by Ungerboeck and with the genetic algorithm, indicating the number of generations required by the genetic algorithm to converge. As can be seen, the genetic algorithm with three memories has found the same optimal value for d free as was found by Ungerboeck, however with 4 and 5 memories the optimal values obtained were different but had the same performances as shown in Fig. 11. The best encoder found by the genetic algorithm for 8 states, 16 states and 32 states and the maximum value of d free after going through different generations are shown in Table 6. Finally, Table 7 shows the variation of values from average to best fitness values.

TABLE III. Initial Population

CH Nm	Initial Population	X Value	Fitness Value f(x)	Selection Pro
1	00110001001001000	25160	2.590	0,0637
2	00110001001001100	25164	2.590	0,0637
3	00110001001011000	25176	2.590	0,0637
4	00110001001100000	25184	2.590	0,0637
5	00110001001100100	25188	2.590	0,0637
6	00110001001110000	25200	2.590	0,0637
7	00110001001101000	25192	2.590	0,0637
8	00110001001101100	25196	2.590	0,0637
9	00110001001111000	25208	2.590	0,0637
10	00110001010010100	25236	2.590	0,0637
11	00110001010001100	25228	2.590	0,0637
12	00110001010011000	25240	2.590	0,0637
13	00110001010000100	25220	3.180	0,0782
14	00110001010010000	25232	3.180	0,0782
15	00110001011000100	25284	3.180	0,0782
		Sum	40.62	
		Average	2.708	
		Max	3.18	

The chromosomes that will reproduce are selected based on their fitness values, using the following probability:

$$\text{P (chromosome I reproduces)} = \frac{f(x_i)}{\sum_{k=1}^{15} f(x_k)} \tag{3}$$

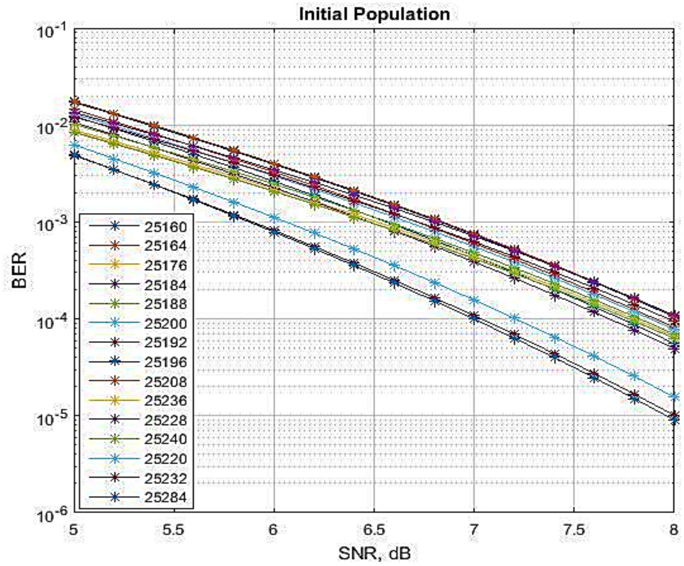


Fig. 6. Comparison between 15 chromosomes of the initial population.

- The simulation illustrated in Fig. 6 shows the comparison between 15 chromosomes of the initial population where the best chromosome corresponds to [00110001011000100] with a d free max value equal to 3.18 and the minimum value for BER (Fig. 7).

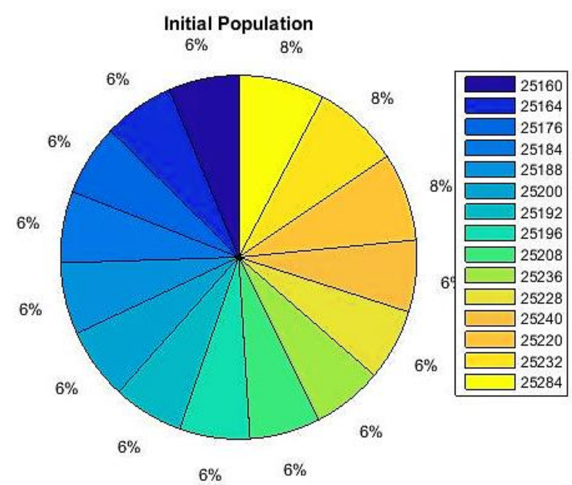


Fig. 7. Presentation of the initial population as a wheel of 15 chromosomes.

TABLE IV. REPRODUCTION AND SECOND GENERATION

CH Nb	New Population	X Value	Fitness Value f(x)	Selection Probability
16	00110001011001000	25288	2.590	0,0503499
17	00110001001100100	25188	2.590	0,0503499
18	00110001010110000	25264	2.590	0,0503499
19	00110001010110100	25268	2.590	0,0503499
20	00110001011100000	25312	2.590	0,0503499
21	00110001011100100	25316	2.590	0,0503499
22	00110001011010000	25296	3.180	0,0618195
23	00110001010011100	25244	3.180	0,0618195
24	00110001011011000	25304	3.180	0,0618195
25	00110001000101100	25132	4.00	0,0777604
26	00110001000111000	25144	4.00	0,0777604
27	00110001000011000	25112	4.590	0,0892301
28	00110001000011100	25116	4.590	0,0892301
29	00110001000100100	25124	4.590	0,0892301
30	001100010001001100	25252	4.590	0,0892301
		Sum	51,44	
		Average	3,429333333	
		Max	4.59	

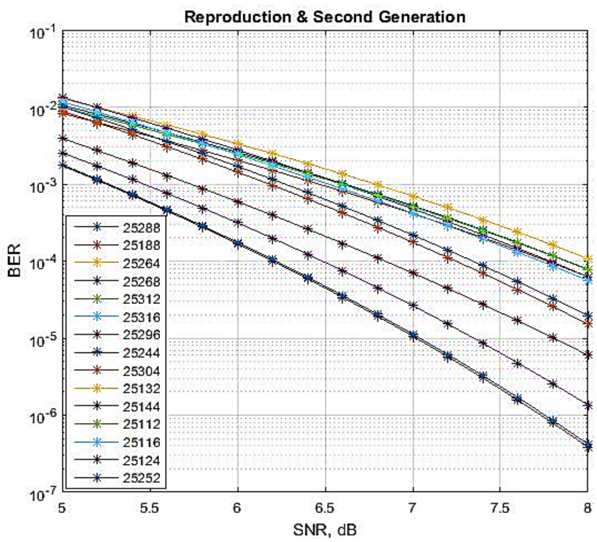


Fig. 8. Comparison between 15 chromosomes of the second generation.

- Now the second generation is tested by the fitness function, and the cycle is repeated. The simulation illustrated in Fig. 8 shows a comparison between 15 chromosomes of the second generation where the best chromosome corresponds to [00110001000101000] and where the standard representation is:

G = [0 0 1; 1 0 0; 0 1 0], T =[0 0;0 1;1 0]; E = [0 0] with a d free max value equal to 4.59 and the minimum value for BER (Fig. 9).

- Fig. 10 shows the first run of a genetic algorithm maximizing the free distance. The red curve is the highest fitness which corresponds to the second generation and the blue curve corresponds to the first generation where average fitness is equal to 3.18. The best solution is reached which corresponds to the chromosome [00110001000101000] with a d free max value equal to 4.59 and the minimum value for BER.

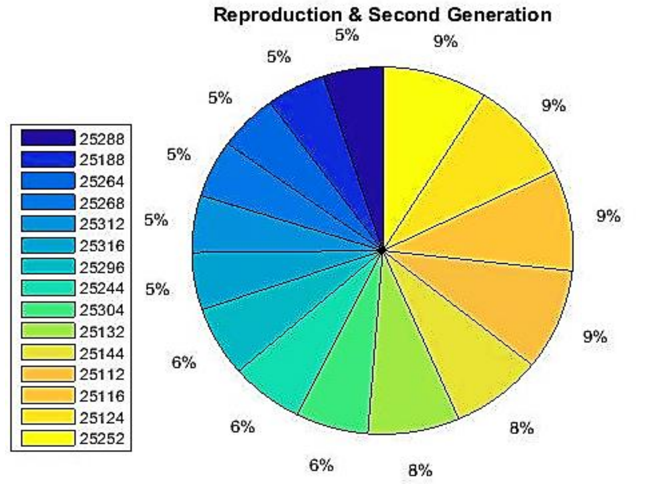


Fig. 9. Presentation of the second population as a wheel of 15 chromosomes.

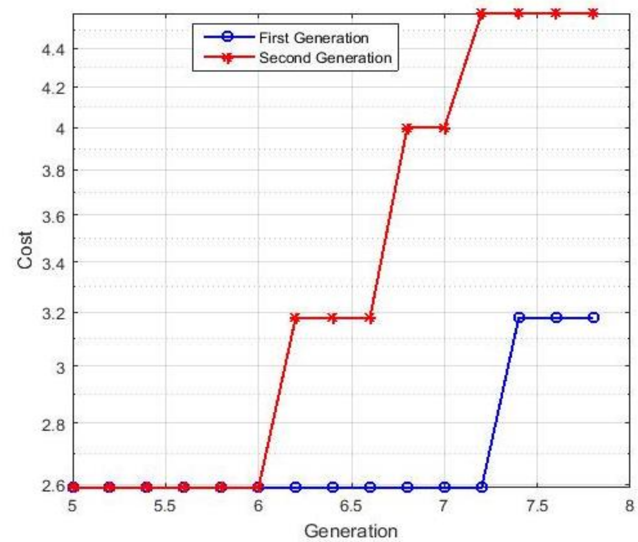


Fig. 10. Comparison between the first and second generations.

TABLE V. VALUE OF D $_{FREE}$ OBTAINED BY UNGERBOECK[1] **[1]** AND THE PROPOSED GENETIC ALGORITHM[2] ALSO LISTED IS THE NUMBER OF GENERATIONS REQUIRED FOR THE GA TO CONVERGE

Number of memories	Modulation	D free from (1)	D free from (2)	Generations
3	PSK	4.586	4.59	20
4	PSK	5.172	5.18	233
5	PSK	5.758	5.77	977

In Fig. 11, the simulation results show that the codes generated by Ungerboeck have the same performance as those generated by genetic algorithm. This is the case after several genetic algorithm code generation iterations conducted until the fitness function value of the chromosome was stabilized and remained stable over many generations at a point where this value converged to the best solution.

TABLE VI. THE BEST CODE GENERATED BY THE GENETIC ALGORITHM

Number of memories	h0	h1	h2	Chromosome
3	**$(11)_8$**	**$(02)_8$**	**$(04)_8$**	001100010 000110 00 G T E
4	**23**	**16**	**10**	$(0001100101000010\ 00010111\ 00)_2 = (6621276)_{10}$
5	**45**	**01**	**16**	000011000001001 0010000010 0110101000 00 = $(6480733856)_{10}$

TABLE VII. VARIATION OF VALUES FROM AVERAGE TO BEST FITNESS VALUES

Number of memories	Fitness Value f(x)								
Three (03) memories	2,59	3.18	4	4,59					
Four (04) memories	2,59	3,18	3,77	4	4,36	4,59	5,18		
Five (05) memories	2,59	3,18	3,77	4	4,36	4,59	4,95	5,18	5.77

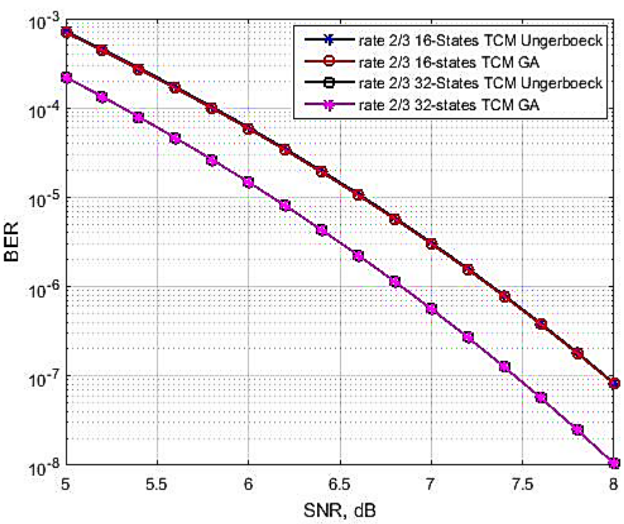


Fig. 11. Comparison between the Ungerboeck codes and those generated by the genetic algorithm in the case of 16 and 32 states.

IV. CONCLUSION

This paper shows improvements which have been obtained by the use of a genetic algorithm for the optimization of TCM schemes, as opposed to other optimization algorithms for this encoder. There are other important details such as the crossover and mutation probabilities, the population size and the iteration number. By applying an appropriate genetic algorithm, a new TCM encoder scheme could be evolved in a multipath channel. These values of the TCM encoder can be adjusted after assessing the algorithm's performance on a few trial runs. Future research attempts to combine genetic algorithms with other optimization algorithms as well as other branches of evolutionary computation, such as neural networks.

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Development and Implementation of the Balanced Scorecard for a Higher Educational Institution using Business Intelligence Tools

Alicia Valdez, Griselda Cortes, Sergio Castaneda, Laura Vazquez
Research Center
Autonomous University of Coahuila
Coahuila, Mexico

Jose Medina, Gerardo Haces
Research Center
Autonomous University of Tamaulipas
Tamaulipas, Mexico

***Abstract*—The objective of designing a strategy for an institution is to create more value and achieve its vision, with clear and coherent strategies, identifying the conditions in which they are currently, the sector in which they work and the different types of competences that generate, as well as the market in general where they perform, to create this type of conditions requires the availability of strategic information to verify the current conditions, to define the strategic line to follow according to internal and external factors, and in this way decide which methods to use to implement the development of a strategy in the organization. This research project was developed in an institution of higher education where the strategic processes were analyzed from different perspectives i.e. financial, customers, internal processes, and training and learning using business intelligence tools, such as Excel Power BI, Power Pivot, Power Query and a relational database for data repository; which helped having agile and effective information for the creation of the balanced scorecard, involving all levels of the organization and academic units; operating key performance indicators (KPI's), for operational and strategic decisions. The results were obtained in form of boards of indicators designed to be visualized in the final view of the software constructed with previously described software tools.**

Keywords*—Business intelligence; balanced scorecard; key performance indicators; BI Tools

I. Introduction

Business intelligence (BI) has had different meanings over the last few years, a pioneer in the creation of the term was Richard Green who in 1996, defined it as "Information processed" cited by [1], for Dresner [2], BI is "a set of concepts and methods to improve the decision-making process, using a fact-based support system." For the Data Warehouse Institute [3] BI is an umbrella term, i.e. the combination of technology, tools and processes that allow the transformation of stored data into information, this information into knowledge and this knowledge apply to a business plan or strategy. In this sense, BI must be part of the business strategy, since it allows the use of optimization of resources, monitoring the fulfillment of the company's objectives and the ability to make good decisions, to obtain better results. BI provides insight and in-depth knowledge of the operation of the organization, through access and analysis of quantitative information sources. Based on the definition of the Data Warehouse Institute, BI is, for the present project, as the group of technologies, techniques, concepts, tools and methods that make it possible to take advantage of historical and current data to support decision making through reports, projections, and predictions. Encouraging, that the data handled contribute to the achievement of the objectives of the institution [4].

Some organizations lack a strategy to create value and achieve their vision with clear and coherent strategies, identifying the conditions in which they are, the sector in which they work and the different types of competencies they generate, as well as the market in general where they work, using the use of computational tools.

To create this kind of conditions requires strategic information to verify the current conditions, to set the strategic line to follow according to internal and external factors, and thus decide what methods to use for implementing the development of a strategy in the organization that allows them to reach the established goals.

The measurement systems have been created and designed with a specific purpose. Used for several decades [5] the Balanced Scorecard (BSC), has a background in the "Tableau de Board", proposed by French engineers in the 70s [6], is a measurement system that aims to visualize the useful information to diagnose the situation and to manage the company [7].

The establishment of a BSC in organizations will constitute a set of established links and shared resources with a common purpose in support of the strategic planning of organizations and increase the competitiveness and productivity [8].

For this research within the methodological framework, the background that gave rise to the problem, where the work method, and the data were collected, the description of the areas involved and the justification of the investigation were reviewed; the purpose of this research is to define key elements for the BSC, such as: To have an organizational framework to specify the structure of the BSC, determine the organization of the project, ensure optimal project management, plan communication and consider critical success factors.

Within the theoretical framework, it is to define the strategic principles, to verify the previous strategic conditions, to establish the strategic line to follow, and to integrate the BSC in the development of the strategy; subsequently, define strategic objectives and link them through cause - effect relationships, select key indicators, set target values and determine strategic actions; the methodology is used to perform the implementation management, deploying the BSC at all levels of the company, directing to the selected business units, creating the link between the business units and finally achieving the expected results and the documentation required to document them for proper management.

Speckbacher, Bischof and Pfeiffer found in their large scale research under German companies a high support for ambivalence in the BSC concept [9], they defined three types of BSC: Type 1, a specific multidimensional framework for strategic performance measurement; Type 2, a Type 1 BSC with cause-effect relationships; and Type 3, a combining of Type 2 BSC with objectives, action plans, results, and connecting incentives with BSC.

Other authors describe the conditions an organization must in order to be able to apply the BSC, and suggest that this method is universally applicable [10].

The BSC [11] provides managers with the instrument they need to navigate towards future competitive success. Today organizations are competing in complex environments and therefore it is vital that they have an accurate understanding of their goals and the methods they must use to achieve them. The BSC translates an organization's strategy and mission into a broad set of performance measures that provide the framework for a strategic management and measurement system. The BSC measures the performance of the organization from four balanced perspectives: Financial, customers, internal processes, and training and growth.

"Business Intelligence applications are decision support tools that enable real-time, interactive access, analysis, and manipulation of business-critical information. These applications provide users with a greater understanding that allows them to identify the opportunities and problems of the business. Users are able to access and leverage a vast amount of information and analyze their relationships and understand the trends that are lately supporting business decisions. These tools prevent a potential loss of knowledge within the enterprise resulting from a massive re-build that is not easy to read or use" [12].

The main objective of this research is to develop and manage the implementation of a BSC, which supports strategic decision making at all levels of an organization, using BI software to identify that strategic actions are carried out in accordance with degree of progress of the defined key performance indicators (KPI's), to ensure optimal project management.

Basically, this study has four sections:

In Section I, the fundamental concepts were shown i.e. the introduction. In Section II, the four perspectives are described. Also, the values of the KPI's were also stated. Thus, Section III describes the methodology, and Section IV describes the principal findings of the project.

II. Balanced Scorecard Perspectives

The perspectives considered for the project were four:

- Financial perspective: Improvement in income, use of funds and asset management.
- Customer perspective: Students-users.
- Internal processes perspective: Organizational value chain improvement.
- Training and learning perspective: Human capital improvement, organizational information.

Each perspective represents an element in the network of activities and processes of the company, giving a global vision in which the strategy is the center of the management systems. The four perspectives are applicable to many companies and educational institutions, government agencies, and others.

Fig. 1 shows the BSC stages, where the four perspectives are the base for obtain strategic results.

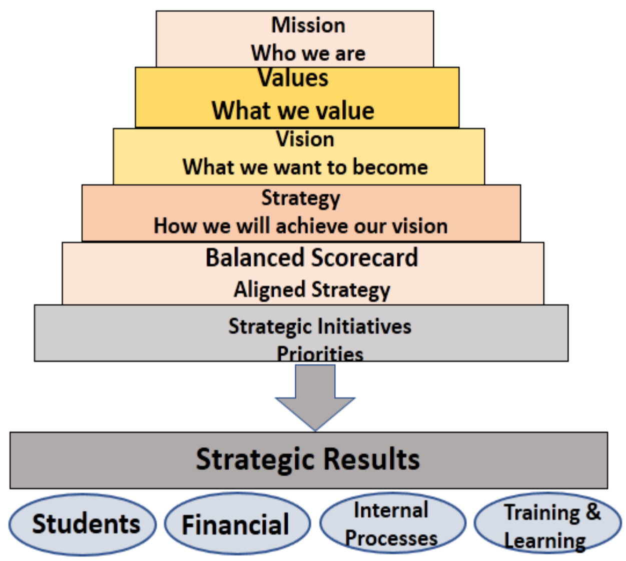

Fig. 1. BSC vision and strategy.

Student's perspective: Every company considers clients as a fundamental element; the company or institution does not exist without clients or in the case of educational institutions students or government departments. Customer satisfaction is intrinsic to business performance, in addition to it depends on economic and financial objectives. However, satisfaction is not always easy to achieve as a basic goal on which others depend. The customer perspective defines the value proposition for the target clients, providing the context for intangible assets to create value. The key questions to answer would be: How is the institution perceived by students about the satisfaction, acquisition, retention and delivery of continuous benefits to the students? What objectives are derived from the characteristics of the students that are necessary to reach the value-added proposals?

Financial perspective: This perspective could be considered as the most classic and implemented to a greater or lesser extent in all companies, educational institutions or government agencies to respond if the expected economic and financial results are being achieved by translating the principles of the strategy into values that reflect the situation and economic trend of the company or institution, therefore describes the tangible results of the strategy in financial terms.

Traditionally, a variety of economic and financial indicators are available for solvency, profitability, cost reduction, etc.

It is necessary to consider the opportunity and necessity of each one of these indicators so that they are used in each moment those that are useful, since otherwise it will have a collection of data facilitated by the indicators without real utility. The key questions to be answered would be: How do the authorities see us? How was research expenditures applied to total expenditures? How were administrative and operational expenditures applied per student? What objectives are derived from the financial expectations of the educational authorities?

Two fundamental aspects can be considered. On the one hand the correct adaptation of objectives and indicators to the business unit in question, and on the other hand the life cycle of the product or service in which the organization or company is located.

Since the financial approach is based on a simple premise, you can only generate more money by selling more or by spending less or making efficient use of resources.

Internal processes perspective: As an extension of the previous perspective, the one relative to internal processes arises. In fact, achieving customer satisfaction by delivering a product or service that meets their expectations needs a set of previous elements that constitute a more or less complex process. The key questions to be answered would be: Which core processes in the value chain would be considered? What objectives are derived from the processes developed by the institution and that are necessary to meet the economic objectives and the students?

This process comprises all the transformation operations in the case of the manufacture and configuration of the service in case of provision of the service, as well as supplies, storage, handling, transportation and distribution. Aspects such as technology, innovation and control complete the process. It is not a question of tackling all processes, but of those considered key and of key importance in the framework of the overall strategy.

In the case of education, it is a matter of covering the improvement of the teaching of face-to-face classes, promoting tutorials, encouraging the use of new technologies, increasing the exchange of new knowledge, implementing management by objectives, increasing quality of services, increase the relationship with the business sector, general services such as quality in classrooms, laboratories, parking, sports courts, and others.

The search for more efficient and effective processes leads to the consideration of procedures such as continuous improvement, which allows mechanisms to detect errors and deficiencies, correct them and improve the process. There is a direct relationship between process management and quality management, which is integrated in the BSC. Time, quality and service become key variables.

The processes describe two fundamental concepts of the strategy, on the one hand from which the products are obtained or the services that are delivered to the clients, on the other hand, the improvement of the processes are directly related with the reduction of costs that in turn are linked to productivity.

Internal processes can be grouped into operational management processes, customer management processes, innovation management processes and social processes.

Training and learning perspective: Customers-students satisfaction, improvement of processes and achievement of economic and financial objectives could not be achieved without fundamental elements such as people, information and organization, designing effective organizational structures.

The human factor in organizations becomes a key asset for the deployment and execution of the strategy and the achievement of the objectives. Information systems, their storage, treatment and dissemination are essential for the development of the objectives.

This perspective identifies the intangible assets that are most important for achieving the desired results for the strategy, identifies which jobs (human capital), which systems (information capital) and what climate (organizational capital), are required to support the processes of value creation; these assets must be aligned with critical internal processes.

The questions to be answered would be: What objectives should be established regarding the capabilities and potentials of the institution, to face the current and future challenges, what strategic resources are considered, can be further improved and created value in staff training, how the organizational climate is considered?

It is about evaluating the ability to innovate, improve and learn, learning and growth are the consequence of professionals involved and motivated.

The continuous training gets an increasing adaptation of the employees to their jobs, and therefore, a better performance producing a spiral of learning-growth that culminates with the best fulfillment of the objectives.

Information is the key piece, so that employees, each at their level can make more convenient decisions at any time.

This perspective reflects the knowledge and skills that the company has, both to produce and provide services, to change and learn.

The foundations on which the BSC is based allow us to reach the objectives of the previous perspectives thanks to the so-called strategic capacities of the company. Intangible assets linked to human capital, information and organization.

III. Methodology

A. Indicators

For this study, qualitative and quantitative data were collected, for five years (2010-2015), giving a mixed approach to the research, which involves a process of collection, analysis and linkage of the two types of data to answer the problem, as a strategic planning process, starting from perspectives, the integration to the BSC allows objectives and goals in each one of them to be carried out in a more focused and integral way.

The selection and definition of the indicators was very important issues of the project, a range between 20 to 32 indicators were used approximately divided in each one of the perspectives:

- Financial: 7 indicators represent 22%.
- Clients (Students): 10 indicators represent 31%.
- Internal Process: 7 indicators represent 22%.
- Learning and Growth: 8 indicators represent 25%.

Some of the indicators are shown in Tables I to IV.

TABLE I. FINANCIAL PERSPECTIVE INDICATORS

KPI	Indicator definition	How is it calculated	Goals
Administrative overhead rate	Efficiency of administrative expenditure	Administrative expenditure/Total students * 100	Efficient economy in administrative expenditure per student
Operating expenses index	Efficiency of operative expenditure	Operative expenditure/Total students * 100	Efficient economy in operative expenditure per student
Revenue index for space rent	Efficiency of operative expenditure	Income for space rent/Total students * 100	Efficient economy in income for space rent

TABLE II. STUDENTS PERSPECTIVE INDICATORS

KPI	Indicator definition	How is it calculated	Goals
New students index	Increase the enrollment of new students	New students/300* 100	Efficiency in the number of new students
Re-entry students index	Increase the enrollment of re-entry students	Re-entry students/700 * 100	Efficiency in the number of re-entry students
Students mobility	Increase students mobility in other universities	Students in mobility/Total students with possibilities * 100	Mobility efficiency

In Table I, three indicators as administrative overhead rate, operating expenses index and revenue index for space rent are shown with its definition, and goal; the responsible is the administrative secretary, and frequency of the measure for the indicator is monthly.

In Table II, the three indicators presented corresponding to the students' perspective, in this case the new students index, the re-entry students index, and the students mobility; this perspective has other indicators as tutoring, fellowships, internships and level of satisfaction of the student regarding student services.

In Table III, the academic program index and the academic agreements index are shown, these indicators corresponding to internal processes that are related with the academic programs quality.

As the objectives respond to a given strategy, the indicators also, so that for each perspective and for each strategy, concrete objectives and values to be reached are quantified through specific indicators. There are two types of indicators:

1) *Inductors:* Measure the actions they take to achieve the goal.

2) *Result*: Measure the degree of obtaining the results.

As a general criterion, no more than two indicators should be established for each objective, the most common being an indicator per objective.

TABLE III. INTERNAL PROCESSES PERSPECTIVE INDICATORS

KPI	Indicator definition	How is it calculated	Goals
Academic program index	Strengthen the academic programs	Quality careers/total careers * 100	Quality careers.
Academic agreements index	Increase the academic agreements	Academic agreement/ proposed agreements * 100	Efficiency in the number of academic agreements

TABLE IV. TRAINING AND LEARNING PERSPECTIVE INDICATORS

KPI	Indicator definition	How is it calculated	Goals
Research projects index	Proposed and approved research projects	Proposed research projects/Approved projects * 100	Research efficiency
Index of teachers with doctorate degree	Teachers with doctorate degree	Teachers with doctorate/total teachers * 100	Efficiency in the number of teachers with doctorate degree

B. BSC Construction

The proposed methodology consists of four phases, shown in Fig. 2.

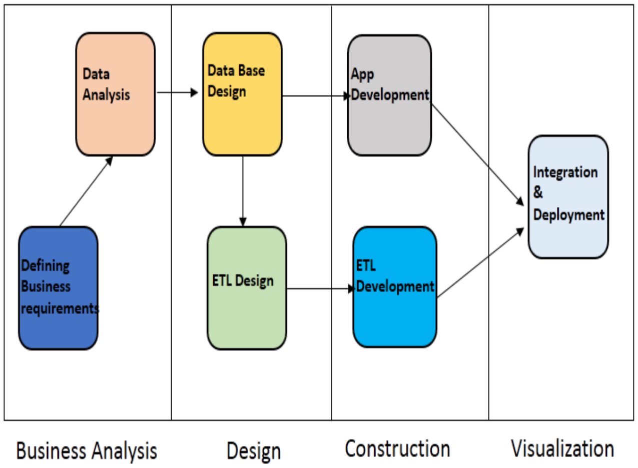

Fig. 2. Methodology phases.

1) Business Analysis Phase

This phase defines the needs of the institution for the collection and measurement of indicators from the four perspectives: finance, customers, internal processes and training and growth. The policies and procedures of the key processes of the institution are also analyzed.

2) Design Phase

With the data collected, the database was designed in the SQL Server 2012 relational software shown in Fig. 3; the tools that will be used for the activities of the design to extract, transform and load (ETL) in this process were selected, formatted and presented to display in the selected software. For basic and advanced analysis, we used SQL Server 2012 with Excel, Power Query [13], Power View and Power Pivot [14]. Fig. 3 shows the design of the data diagram for the application that will serve for the storage of the obtained data and later analysis.

3) Construction Phase

In this phase were built the programs used for the analysis of the data and its subsequent loading and deployment activities. Also in this phase the communication of data between Excel and BI tools was established with queries and reports of large volumes of tabular data.

4) Visualization Phase

Indicators panels were designed to be visualized in the final view of the software. The analysis of mission-critical data is visualized, in addition to the fundamental needs of the data used, with an information screen viewer and interactive links to the details of key performance indicators (KPI's), following the company model.

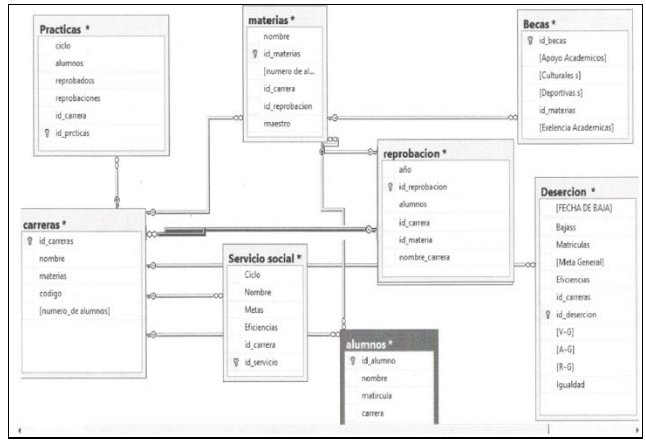

Fig. 3. Database design.

Also were created line graphs, highlights trends, bar graphs, standing out categorical comparisons within a dimension and nominal comparisons through the data.

Once the mission, the vision, the business strategy, and the strategic objectives were defined, the next step was selected the corresponding financial and non-financial indicators, as well as their predicted values. These strategic objectives must be concretized in strategic actions that ensure their achievement; each strategic action was assigned a responsibility, a deadline and a budget. At this step from vision to strategic definition and its achievement in actions, Kaplan and Norton [11] called it "Transforming strategy into action".

Strategic objectives, indicators, values and strategic actions were interrelated through cause-effect relationships. One of the fundamental characteristics of the BSC is the combination of financial and non-financial indicators, however it is not the most relevant, and since previously organizations have developed dashboards that combine indicators, financial and non-financial.

Kaplan and Norton [11] indicate that management processes and programs were built around structures. Traditional management systems have been built around a financial structure.

C. BI Tools used

1) Excel power BI

This function is used to connect data from a wide range of sources, such as tables of public websites, corporate data in databases, cloud-based sources such as Azure, unstructured data, to display as tables within a spreadsheet.

2) Power pivot

This tool allows to handle different types of data sources, with large volumes of data, handle multiple selection of data under the concept of data segmentation; automatically groups dates by years, quarters and months, expands and contracts dynamic data, Excel and Power Pivot, allow you to create a data model, as well as a set of tables with relationships.

3) Power query

Tool with data search functions, transformations and cleaning of them for exploitation in Excel (formerly known as “Data Explorer”). Power Query enhances Excel’s BI with an intuitive and consistent experience to discover, combine and refine data in a wide variety of sources such as relational, structured and semi-structured, OData, Web, Hadoop, Azure, Marketplace and much more, plus Power Query also gives you the ability to search for public data.

Other software was used for the realization of this project, but these tools were the main ones.

IV. Results

For this case, we analyzed the exposed situation of the Autonomous University of Coahuila, focused mainly on the situation presented in the Faculty of Mechanical and Electrical Engineering, supported by documentation provided, its strategic reflection is complemented by a SWOT analysis.

The BSC core is the strategic map which, when used, helps us to be sure that our strategy is clear enough and can be operational by converting big ideas and visions into a structured, operative and actionable strategy that clearly points out each of the company’s units bring differential and balanced value to the achievement of the organization’s strategy.

For the case of the central region of the state, the enrollment behavior at this level is 14,516 students graduated from the school year 2014 to 2015, if we consider the increment factor of 1.49 per year, the enrollment for 2015-2016 would be in an increase to 16,678 students graduated from the upper middle level of the central region of the state of Coahuila, which represents a fairly acceptable level of graduates of upper middle level.

Fig. 4 displays the absorption rate of the Faculty of Mechanical and Electrical Engineering according to the 16,678 graduates of upper secondary level is 1.17%, which represents 196 new students, who were accepted in the school year 2015-2016; it should be noted that the capacity of absorption can be up to 405 students, product of the capacity in classrooms and spaces that we count, since in the case of the year 2011-2012 a total of 304 students of new entrance were accepted, according to the analysis realized and the goal, which we are proposing based on the analysis of the last 5 years and that we define in this section, we exceed the calculated goal of 298 students of new income.

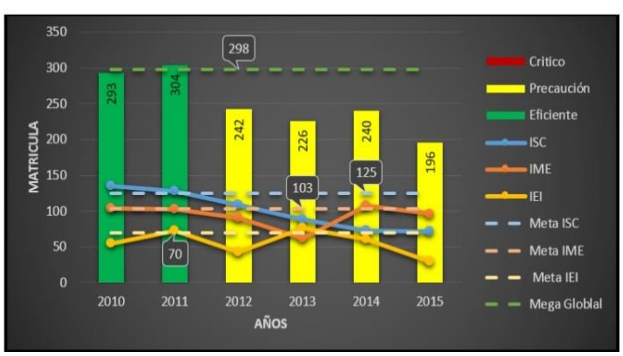

Fig. 4. Indicators of new entry, re-entry and total enrollment.

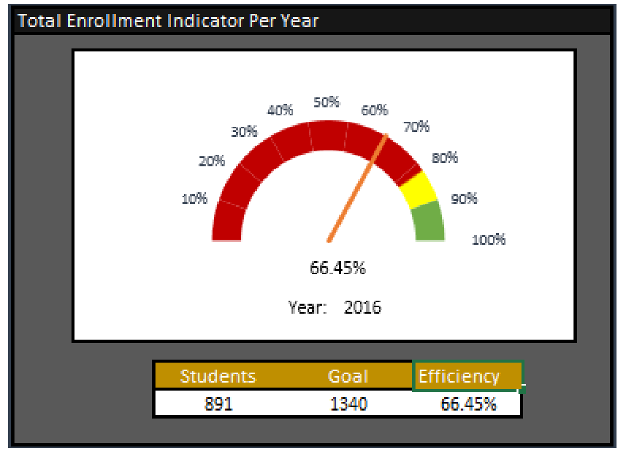

Fig. 5. KPI Total enrollment at 2016 year.

Finally, in the analysis carried out in 2015-2016 school year, the faculty absorbed 196 students, representing 65.77% with respect to the established goal, which is of 298 accepted students of new income.

In Fig. 5, the indicator obtained is in red, this dashboard was obtained from Power BI, this is a low level of acceptance of faculty for incoming and re-entry students. Design an action plan to help solve the problems that help increase the indicators, which may include marketing strategies, create new careers, and create mechanisms for evaluation and academic monitoring.

Because of the analysis of the information obtained there is a low level of student participation in research and technological development projects led by full-time teachers.

V. Conclusion

Once the maps were constructed and detailed, the strategic objectives are clearly defined, the selection of indicators is the natural continuation of the process, where the indicator is an element of objective measurement, which allows the establishment of goals over time; Goals that are quantifiable, ambitious, measurable, controllable and achievable; Which mark the milestones and desired rhythm of the evolution of the strategy in function of the current situation.

It should be noted that in the development of the BSC indicators now play an important role but in no case isolated and as an end, but always as a means directly related to the strategic objectives they measure; who in turn ere ordered in perspectives and related through cause-effect relationships within strategic maps.

The implementation of the BI solution allowed appreciate how the use of IT, and especially BI, can support the processes of management and decisions in contexts such as university education and contribute to strengthening initiatives aimed at improving decision-making process supported with the values obtained from the analyzed indicators.

The methodology used facilitated the identification of processes, activities and tasks of a BI solution.

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Developing a New Hybrid Cipher Algorithm using DNA and RC4

Rami k. Ahmed
Dept. of Computer Science
College of Science, University of Baghdad
Baghdad, Iraq

Imad J. Mohammed
Dept. of Computer Science
College of Science, University of Baghdad
Baghdad, Iraq

***Abstract*—This paper proposes a new hybrid security algorithm called RC4-DNA-Alg. It combines the symmetric stream cipher RC4 algorithm with DNA-indexing algorithm to provide secured data hiding with high complexity inside steganography framework. While RC4 represent one of the widely used algorithms in network security protocols, such as Secure Sockets Layer (SSL), a DNA cryptography considered as a modern branch of cryptography that combines the traditional cryptographic techniques with the power of the genetic material The performance evaluation of the proposed algorithm is measured based on three parameters (conditional entropy, randomness tests and encryption time). The result shows outperformance in security and distorted in hybrid Cipher compared to the native RC4.**

Keywords*—Rivest Cipher 4 (RC4); Secure Sockets Layer (SSL); Deoxyribonucleic acid (DNA); Rivest Cipher 4-Deoxyribonucleic acid-Algorithm (RC4-DNA-Alg)

I. Introduction

As a society, we are relying increasingly on rapid access and information processing. The proliferation of cheap computers and computer network increased the problem of unauthorized access and data theft. It may be contributed in the need to take into account the security engineering mathematics qualities and physical security systems to develop more efficient approaches, Cryptography is one of them. The demand for cryptographic technologies has increased because of the need to transmit information privately and secrecy to public networks that can intercept. In the past, encryption was used only by governments and military. At present, Cryptography used available to anyone. It is considered one of the most important means of maintaining the confidentiality of information, privacy and access control. It also used in the field of identity authentication and many other fields [1].

This paper is organized as follows: Section II describes some of the research work related to this study. Section III describes a brief about background of encryption and presents the main cryptography algorithms used in this study. Section IV explains in details the proposed algorithm for hybrid algorithm cryptography, Including all components and technologies involved. Section V discusses the performance analysis and the results. Section VI describes in brief a conclusion of this study.

II. Related Work

In 2013, Naser and et al. [12] developed a hybrid algorithm by combining three algorithms AES, RC4, and a serpent. The hybrid algorithm provided protection against most of the attacks using encryption and tried to ensure the confidentiality and secrecy of information. In 2015, Rafael and Antonio [13] proposed a modification for RC4 algorithm (called RC4itz) using the properties of the Spritz algorithm. RC4itz outperforms AES, RC4 and Spritz algorithms in term of performance, secrecy and randomness. In 2014 Himanshu and Vishal [15] developed a new hybrid approach using two algorithms AES and DNA. In their algorithm, the information split into two segments: one encrypted with AES (128) and other segment used DNA scenography to hide the information. In 2016, Karandeep [14] developed a new novel technique which is a double security layer algorithm. This algorithm consists of RSA algorithm and Deoxyribonucleic Acid (DNA) using cloud environment. The former, DNA used to encrypt information followed by RSA algorithm to encrypt cipher text result from DNA algorithm before storing in cloud servers. In 2011, Xue Sun et al. [10] present a new hybrid encryption algorithm to protect the instant messaging system using the AES for encryption, SHA-1 for authentication and RSA algorithms for key exchange to implement a hybrid encryption system. This was implemented over an Extensible Messaging and Presence Protocol (XMPP) based IM server and Java based clients. In 2016, Tutt and et al. [15] Proposed an efficient secure end-to-end messaging system that Consists of a combination of symmetric key cryptography (AES 256 bit) with temporary keys for individual message security and using Elliptic Curve Diffie-Hellman cryptography for key exchange and message authentication (HMAC-SHA384).

III. Background of Encryption

A. Symmetric and Asymmetric Encryption

Symmetric encryption also called secret key encryption where both the sender and the receiver depend on the same secret key where the sender uses the key to encrypt the message while the receiver uses the same key to decrypt the cipher text. This method is faster than the public key encryption method and less complex [3]. Some examples of Symmetric encryption: DES, 3DES, 3DES, AES and IDEA. Asymmetric encryption also called public key encryption; it uses two keys instead of single key [2]. The public key can be published while the private key kept in secret. The information encrypted using the public key and then can be decrypted using private key [3]. Asymmetric encryption works slower than symmetric encryption and sometimes preferred to encrypt the secret key for symmetric encryption over digital networks safely. Some examples of Asymmetric encryption: PGP, DSA, Deffie-Hellman and RSA. Fig. 1 illustrates the two types of encryption.

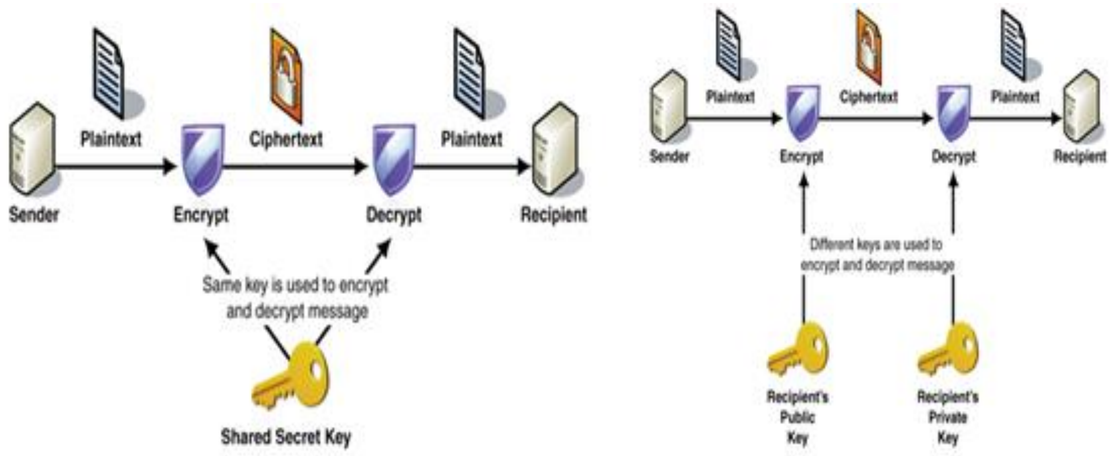

Fig. 1. Symmetric and asymmetric encryption [3].

B. Stream Cipher and RC4

Stream Cipher is a Symmetric key cipher where the plain text and the pseudo-random key (key stream) are combined by xor operation. In the encryption, each byte of plain text is encrypted with the corresponding character of the key stream. An alternate name is the cipher state, where the encryption of each character depends on the current state. RC4 no longer provides complete protection also it may generate a weak stream key as a result of user-defined weak key, but still widely used in different applications due to the ease of use as well as its speed in encryption and decryption [4], [7].

RC4 algorithm itself does not encrypt anything but generates pseudo-random values called the Key stream used for encryption using xor with the original text then decryption using xor operation with the cipher text [5]. RC4 algorithm divided into two basic phases (Algorithm 1 and Algorithm 2 in our context):

Phase 1: key-scheduling phase (KSA) as a preliminary stage that requires the following processes:

- A user-defined encryption key is specified between 0 and 255 characters (as length).
- A state Array (256 bytes) created and denoted by state. Initialized from 0 to 255 values, several substitutions performed on state array by combining the ASCII code of the encryption key with the state array cells. A new state array is produced that contains all possible cases, but arranged random [6].

The original version of RC4-KSA can be summarized in Algorithm 1.

Phase 2: Pseudo-Random Generation Algorithm PRGA. At this phase, a new state array created with Pseudo-random values [6]. When the process of generating Pseudo-Random bytes completed, the encryption process begins by executing xor operation between the key stream and the original text, the decryption process executed in the same manner by doing the xor operation between the key stream and the cipher text to produce the original text. The PRGA can be summarized in Algorithm 2.

Algorithm I. KEY SCHEDULING ALGORITHM (KSA)

```
For i = 0 to 255
   state [ i ] = i
Next i
j = 0
For i = 0 to 255
   j = ( j + state [ i ] + key [ i mod key.length ] )   mod 255
   Swap (state [ i ] , state [ j ])
Next i
call algorithm.2
```

Algorithm II. ALGORITHM 2: PSEUDO RANDOM GENERATOR ALGORITHM (PRGA)

```
i = 0
j = 0
For x = 0 to message.length - 1
    i = ( i + 1 ) mod 256
    j = ( j + state [ i ] ) mod 256
    Swap ( state [ i ] , state [ j ] )
    t = ( state [ i ] + state [ j ] ) mod 256
   // Pseudo-random values
   // Encryption step
       Cipher_text [ x ]  = ( Plain_text [ x ] xor state [ t ] ) mod 256
Next x
```

C. DNA Algorithm

Biological DNA can be used in steganography and cryptography as the storage material. Molecular computations can be performed with biological DNA structures and then applied on the classical ciphers [8]. Several projects in genome sequencing offer the possibility to exploit digital DNA databases (NCBI) for the cryptographic purposes. Deoxyribose Nucleic Acid (DNA) has a helical shape, included of 2 long strands of nucleotides. A nucleotide has one of 4 bases: A – adenine, C – cytosine, T – thymine or G – guanine. Utilizing coding method, any digital data can be transformed easily into DNA sequence using Table 1 [8].

TABLE I. DNA GENETIC CODE

Binary	DNA Chromosome
00	A
01	C
10	G
11	T

a) Principle of DNA algorithm [9]:

- Each character of text information converts to ASCII code, for example : - original message is “ramy” in ASCII will be : 114 97 109 121
- Convert ASCII code to binary sequence: 01110010 01100001 01101101 01111001
- Convert binary sequence to DNA sequence using DNA Genetic Code (Table 1): CTAG CGAC CGTC CTGC.

IV. PROPOSAL ALGORITHM (RC4-DNA-ALG)

It is hybrid algorithm, called RC4-DNA-Alg, a modified version of RC4 applied by adding new state called (new-state) that supports DNA indexing and consequently scenography technology.

A. DNA Indexing Algorithm

DNA Indexing is a stream cipher and symmetric algorithm that encrypts one byte at a time. The bases of DNA cryptography are to transform one byte of data to a series of four chromosomal. The next stage is to find four series out of the chromosomal series selected as a key for encryption. The chromosomal series selected from public available databases (NCBI database website) and used in the implementation of our algorithm, an instance of the selected DNA database presented in Fig. 2. DNA Indexing can regard as homophonic substitution cryptography.

The fundamental of homophonic substitution is to make an array where every Byte of the letters has a specific number of replacement values. The substitution operation of DNA Indexing cipher is simple to achieve, but the reverse process is complex without knowing the key because the distribution pattern of the cipher text is completely different from that of the plaintext [11]. Each byte of plain text has a set of values used in the replacement. The number of replacement values for a byte will depend on its appearance in the chromosome. If someone wants to reuse the same key for many encryptions, then it will be useful to transform this cipher into a homophonic one [10].

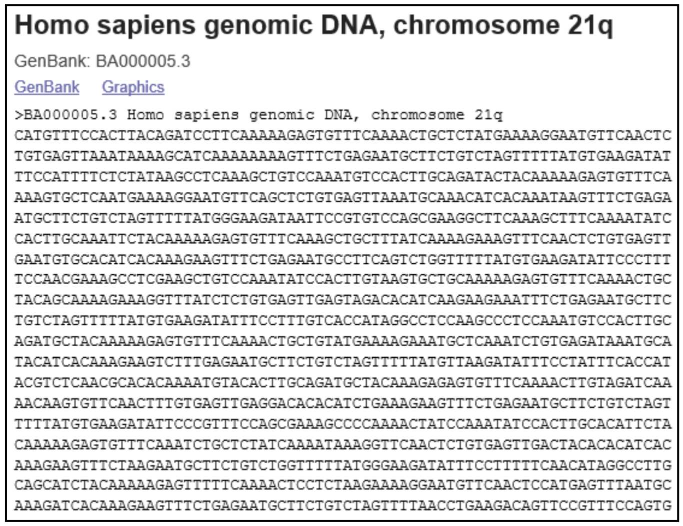

Fig. 2. Chromosomal sequences from a genetic database (NCBI).

B. DNA Indexing Process

Encryption process can be summarized in the following pseudo code 1:

Step 1: Key dictionary calculation:

- Convert every Byte of plain text into DNA series, for example:- Current state byte=114=01110010 ➔ 11=T, 01=C, 00=A, 10=G ➔ 114=01110010=CTAG
- A search performed for every 4 chromosomal DNA out of the NCBI chromosomal series, the index of that position saved in the key dictionary.
- Finally, each byte of plaintext may have multi indexes in the key dictionary, for example (Table 2):

TABLE II. KEY DICTIONARY OF GENETIC DATABASE (NCBI)

DNA	Key indexing
AAAA	221, 1036, 5002, 32654 ….
AAAT	12, 566, 9354 ….
AAAG	856, 6549, 22354 ….
AAAC	23, 66, 647, 6985, 63745 ….
......	
CCCC	478, 6324, 26583 ….

Step 2: The encryption process performed by replacing one byte of plain text with a value from the key dictionary as illustrated in Table 2. For example, the substitutions or the pattern (CTAG) could be replaced with any one of (65, 3154, 4687, 9637, 13586, 25697 or 36548).

Step 3: The final output of the encryption process consists of key index as integer value, for example: Current new-state byte selected from the substitutions = 36548.

Fig. 3 depicts the block diagram of the proposed algorithm (RC4-DNA-Alg).

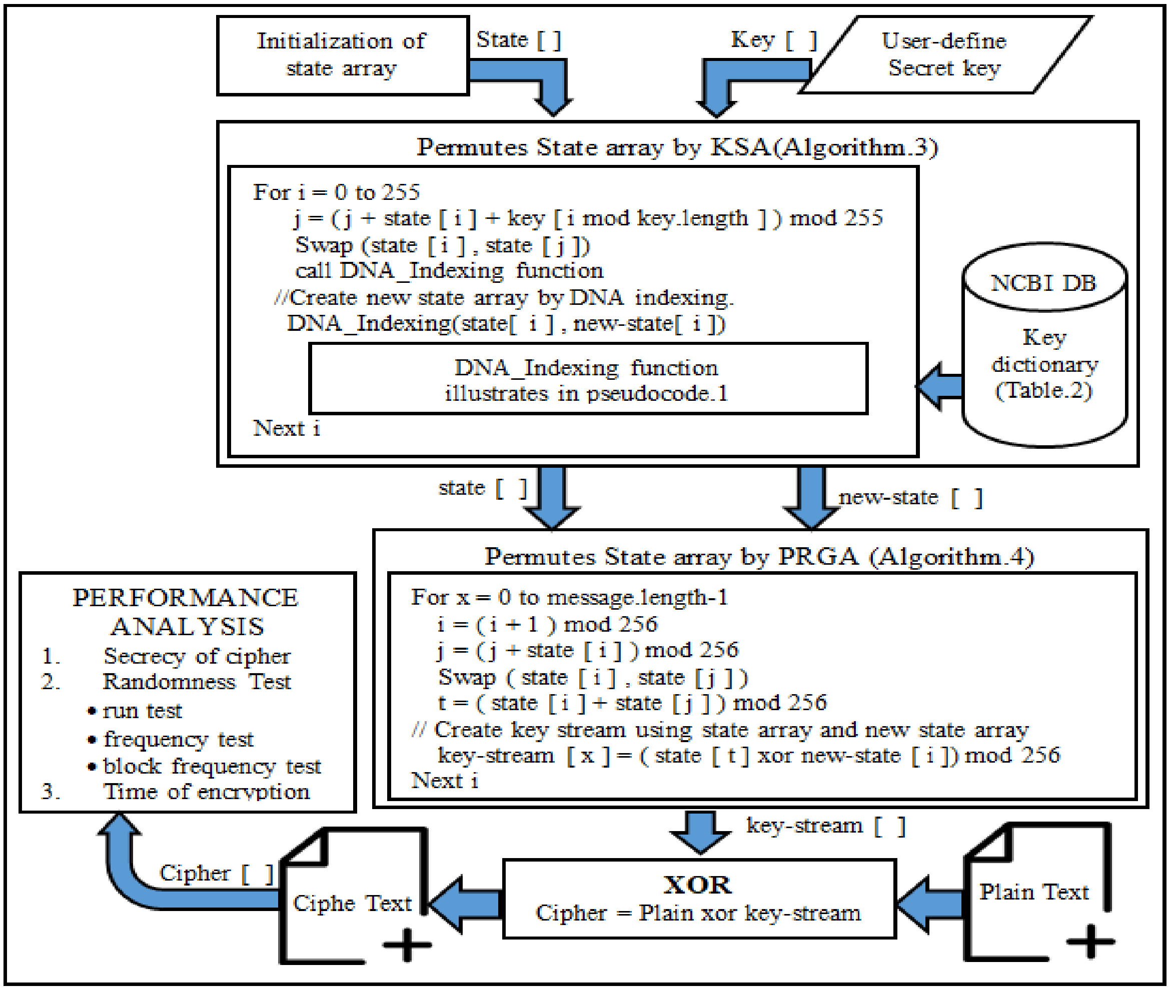

Fig. 3. Block diagram of the proposed algorithm (RC4-DNA-Alg).

In our proposed design, the modified KSA can be summarized in Algorithm 3.

Another modification suggested improving the original PRGA as appears in Algorithm 4.

The decryption process uses the same chromosomal sequence of the encryption process as part of symmetry criteria.

- Every integer value of cipher text used as an index into the key dictionary.
- Retrieve the four chromosomes from the indicated index of key dictionary.
- Every Byte of plain text reconstructed by convert every four chromosome into a binary then converts it to ASCII code (of plain text).

Algorithm III. Modified Key Scheduling Algorithm (KSA)

For i = 0 to 255
  state [i] = i
Next i
j = 0
For i = 0 to 255
  j = (j + state [i] + key [i mod key.length]) mod 255
  Swap (state [i] , state [j])
//added step to the original KSA (illustrates in pseudocode.1).
  DNA_Indexing(state [i] , new-state [i])
Next i
call Algorithm.4

Algorithm IV. The Modified Pseudo Random Generator Algorithm (PRGA)

i = 0
j = 0
For x = 0 to message.length-1
  i = (i + 1) mod 256
  j = (j + state [i]) mod 256
  Swap (state [i] , state [j])
  t = (state [i] + state [j]) mod 256
//modified step of original PRGA algorithm by adding a new state.
  key-stream [x] = (state [t] xor new-state [i]) mod 256
  Cipher_text [x] = (Plain_text [x] xor key-stream [x]) mod 256
Next x

V. Performance Analysis

This section introduces the performance analysis of RC4-DNA-Alg based on three main parameters; Cipher Secrecy, Randomness, and Entropy. In this paper, the same inputs are used to examine the original and the modified version of RC4 algorithm in terms of Average secrecy, Randomness and encryption time using 100 random plaintexts for of variable length (128,256,512 and 1024 byte) and 100 random key of variable length (32,64,128 and 256 byte).

A. Secrecy of Cipher

Measurement is entropy. It represents the amount of information exist in a random variable, the exchanged information, and the amount of information shared between two random variables. The key equivocation H (K|C) defined as “the amount of information about the key used that is revealed by the cipher text observed” As shown in the following equation:

$$H(K \mid C) = \sum_{j=1}^{l} \sum_{i=1}^{n} P_k(j) * P_{k,c}(i,j) \log_2 P_{k,c}(i,j)$$

Where, H denotes entropy, K for key, C for cipher text, P for probability, l for length key, n for length of cipher text.

Table 3 shows RC4 compared to RC4-DNA-Alg on average. It is observed that RC4-DNA-Alg provides more secrecy compared to RC4.

TABLE III. The Proposed RC4-DNA-ALG Compared to RC4 based on Average Secrecy

Plaintext Size	Key Size	Average Secrecy Value	
		RC4	RC4-DNA-Alg
128	32	0.32	0.422
	64	0.68	0.789
	128	0.907	0.998
	256	0.875	0.984
256	32	0.321	0.424
	64	0.583	0.691
	128	0.773	0.983
	256	0.809	0.99
512	32	0.351	0.424
	64	0.626	0.793
	128	0.825	0.986
	256	0.891	0.991
1024	32	0.361	0.425
	64	0.686	0.793
	128	0.815	0.986
	256	0.862	0.993
Wins / total test		0/16	16/16

TABLE IV. The Proposed RC4-DNA-ALG Compared to RC4 based on Average Randomness

Plaintext	Key Size	Run Test		Frequency (Monobit)		Frequency Block	
		RC4	RC4-DNA-Alg	RC4	RC4-DNA-Alg	RC4	RC4-DNA-Alg
128	32	0.417	0.502	0.491	0.488	0.399	0.503
	64	0.419	0.504	0.418	0.492	0.408	0.503
	128	0.502	0.5	0.497	0.496	0.452	0.502
	256	0.404	0.498	0.49	0.49	0.473	0.507
256	32	0.42	0.502	0.429	0.495	0.401	0.502
	64	0.503	0.499	0.495	0.49	0.41	0.502
	128	0.435	0.499	0.498	0.491	0.5	0.499
	256	0.496	0.505	0.441	0.493	0.468	0.504
512	32	0.397	0.497	0.42	0.5	0.449	0.504
	64	0.414	0.502	0.406	0.497	0.503	0.5
	128	0.393	0.5	0.454	0.502	0.46	0.507
	256	0.399	0.501	0.501	0.498	0.478	0.507
1024	32	0.396	0.5	0.502	0.5	0.42	0.505
	64	0.504	0.497	0.501	0.494	0.453	0.507
	128	0.405	0.501	0.498	0.497	0.471	0.507
	256	0.5	0.497	0.436	0.5	0.454	0.509
Wins / total test		4\16	12\16	9\16	7\16	2\16	14\16

B. Randomness Test

Randomness Test is a set of algorithms that find out whether the distribution of data is random. In this paper, three algorithms of Randomness (run test, frequency test and block frequency test) are implemented to evaluate the randomness of cipher text (Table 4). It can be observed that RC4-DNA-Alg provides more randomness values compared to native RC4 (shadow color).

C. Time of Encryption

Encryption time (Table 5) has been tested on a machine using CPU Intel core i5 2.4 GHz and RAM 8 GB under Microsoft windows 10 enterprise 64-bit.

Table 6 shows the result summary of encryption time.

TABLE V. THE PROPOSED RC4-DNA-ALG COMPARED TO RC4 BASED ON AVERAGE ENCRYPTION TIME

Plaintext Size	Key Size	Average Encryption Time (ms)	
		RC4	RC4-DNA-Alg
128	32	0.401	0.522
	64	0.402	0.529
	128	0.41	0.538
	256	0.414	0.584
256	32	0.554	0.624
	64	0.562	0.641
	128	0.567	0.681
	256	0.576	0.69
512	32	0.836	0.924
	64	0.843	0.993
	128	0.848	1.086
	256	0.857	1.091
1024	32	1.385	1.425
	64	1.435	1.793
	128	1.593	1.986
	256	1.612	1.993
Wins / total test		16/16	0/16

TABLE VI. SUMMARY OF RESULTS

Parameters / algorithms	RC4	RC4-DNA-Alg
	win	win
Secrecy of cipher	0 %	100 %
Run Test	25 %	75 %
Frequency (Monobit)	56.25 %	43.75 %
Frequency Block	12.5 %	87.5 %
Average encryption time (in ms)	0.832	1.007 (17.5 % overhead)

VI. CONCLUSIONS

Current research introduced a new hybrid algorithm (RC4-DNA-Alg) by combining RC4 and DNA algorithms. It is validated that RC4-DNA-Alg enhanced the secrecy level of the cipher text for all tested sizes of plaintext using four different key sizes (32, 64, 128 and 256 Bytes). Furthermore, got more stable randomness test than native RC4. The enhancement steps added an overhead around (17.50%) to the execution time of original RC4. In future work will focus on developing a key exchange algorithm in order to implement the instant messaging system based on this study.

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Evaluating Cancer Treatment Alternatives using Fuzzy PROMETHEE Method

Dilber Uzun Ozsahin[a,b], Berna Uzun[a], Musa Sani Musa[a], Abdulkader Helwan[a], Chidi Nwekwo Wilson[a], Fatih Veysel Nurçin[a], Niyazi Şentürk[a], Ilker Ozsahin[a]

[a]Near East University, Near East Boulevard, ZIP: 99138Nicosia / TRNCMersin 10 – Turkey

[b]Gordon Center for Medical Imaging, Massachusetts General Hospital & Harvard Medical School, 125 Nashua St., Boston, MA 02114 U.S.A.

***Abstract*—The aim of this study is to apply the principle of multi-criteria decision making theories on various types of cancer treatment techniques. Cancer is an abnormal cell that divides in an uncontrolled manner, it is a growth (tumor) that starts when alterations in genes make one cell to grow and multiply rapidly. Eventually, these cells may metastasize to other tissues. The primary factors that influence the comprehensive treatment plan of cancer include, but not limited to genetic factors, patient general health condition, explicit characteristic of cancer, and even purpose of the treatment. Other factors which are also essential include treatment duration, cost of treatment, comfortability, side effects and percentage of survival rate. The latter factors play an important role in the course of treatment and are therefore needed in order to evaluate the several treatment procedures. The outcome of the decision-making theories on these treatment procedures will help the concerned parties such as the patients, oncologists, and the hospital management. The most common cancer treatment techniques were evaluated and compared based on certain criteria using Fuzzy PROMETHEE decision-making theory.**

Keywords*—*Cancer treatment alternatives; multi criteria decision making; Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE); fuzzy PROMETHEE

I. Introduction

Cancer is an abnormal cell that divides in an uncontrolled manner, it starts when alterations in genes make one cell to grow and multiply rapidly. Eventually, these cells may metastasize to other tissues. The primary factors that influence the comprehensive treatment plan of cancer include, but not limited to genetic factors, patient general health condition, explicit characteristic of cancer, and even purpose of the treatment. There are various treatment techniques such as; chemotherapy, radiotherapy, hadron therapy, surgery, immunotherapy, and hormone therapy [1]. The primary factors that influence the treatment decision of particular cancer include; patient characteristic, disease characteristic and treatment basis [2]. Apart from the primary factors, other factors which include treatment duration, cost of treatment, Comfortability, side effects and percentage of survival rate play important role in the course of treatment and are therefore needed in order to evaluate the several treatment procedures.

PROMETHEE and Fuzzy PROMETHEE are multi-criteria decision-making techniques which are explained in Section 3. In this paper, we used Fuzzy PROMETHEE technique to evaluate the cancer treatment alternatives corresponding to their parameters.

This paper is organized as follows: In Section 1, the basic information about the cancer treatment alternatives is presented. In Section 2, PROMETHEE and fuzzy PROMETHEE techniques are shown and the proposed approach is presented. In Section 3, the results are shown. Lastly, we conclude the paper in Section 4.

A. Chemotherapy

Cancer chemotherapy uses anticancer drugs that are meant to destroy the cancer cells [3]. These drugs are being delivered orally or intravenously (injected into a vein), making its way to the bloodstream to get to the cancer cells at different parts of the body [4]. Due to the mode of operation of this therapy technique, it has unique systemic effects [5]. The way the therapy works is by slowing or inhibiting the growth of cancer cells which grow and divide rapidly. The downside of this procedure is that healthy cells that are rapidly dividing are harmed too. The noticeable side effect of this procedure arises from damage to healthy cells, but the effects may wear off when therapy is over [4].

Chemotherapy is also used alongside other modalities for treatment to ensure greater effectiveness and specificity on cancer cells. The Adjuvant chemotherapy is undergone after radiation therapy or surgery to completely destroy cancer cells that might have been left after previous treatment [5]. Neo-adjuvant chemotherapy is when treatment is given to shrink the cancer cells before surgery or radiation therapy to maximize treatment efficacy [3]. Other strategies include Consolidation (given to increase cure rate), Induction (given to induce complete response to treatment), Intensification (given to effect a longer remission), Maintenance (given to delay regrowth of residual cancer cells), Palliative (given to control symptoms), and Salvage (given to patient whose symptoms have recurred or failed) [5]. The treatment regime to be used depends on the type of cancer and its severity. The above-mentioned strategies can cure, control and ease cancer symptoms [4].

B. Radiotherapy

Radiotherapy is highly competent in the treatment of a local tumor. However, clinical problems arise as a result of the radioresistance of intrinsic tumour cells to treatment. This treatment utilizes X-rays of relatively high-energy to destroy tumour cells or inhibit their growth [6]. Two main types of such treatment are available, External beam therapy which involves bombarding the tumour with radiation from equipment outside the body and Internal radiation treatment which uses a radioactive substance enclosed in a delivery device such as catheters, seeds, needles or wires placed near or directly into cancer [7]. Furthermore, the stage and type of cancer to be treated determine which therapy procedures should be administered. External beam treatment is used in the treatment of breast cancer whereas internal beam treatment with a radionuclide (Strontium-89) is employed to lessen bone pain resulting from breast cancer that has metastasized to the bones around the breast. Strontium-89 is administered intravenously and travels to the bone surface. The released radiation destroys tumour cells in the bones [8].

Brachytherapy is an internal radiation therapy that conveys radiation to diseased tissue from a radioactive source positioned inside the body. Brachytherapy can convey greater doses of radiation to cancer cells than external-beam radiation therapy while inflicting less damage to healthy tissue. This therapy employs the use of several techniques to treat cancer, and they are briefly discussed. Interstitial brachytherapy makes use of radiation source placed within a tumour. Intracavitary brachytherapy uses a source positioned inside a body cavity or a surgical cavity, e.g the chest cavity neighbouring a tumour [9]. Episcleral brachytherapy is used in the treatment of melanoma in the eye, with its source attached to the eye. The radioactive isotopes used in brachytherapy are enclosed in tiny pellets or "seeds". Catheters, needles, or other types of carrier are used as the delivery tools to place the seeds into patients. The resulting decay of the isotopes naturally, then gives off radiation that kills nearby cancer cells [10]. When at the location after a few weeks or months, the isotopes decay entirely and ceases to emit radiation. These seeds cause no harm when left in the body.

C. Hadron Therapy

This is a form of radiotherapy which uses (protons, neutrons and other ions) to treat cancer. Due to their unique radiobiological properties, these particles have the ability to penetrate tissues and deposit their peak energy. Hadrons are subatomic particles that are influenced by a strong nuclear force which binds particles in harmony within the atomic nucleus [11]. Common examples of hadrons are the neutrons and protons and that form the atomic nuclei. Protons, neutrons, and light ions such as carbon, helium, neon and oxygen are the hadrons recently used in radiotherapy [12]. These beams posses physical and radiobiological attributes which are entirely different from the X-ray and gamma ray beams used in typical radiotherapy. The interaction between charged hadrons and matter is so free which results in a well-defined spreading of the dose in depth. Light ions deposit at the end of their track a significant portion of their energy, resulting in strong local ionization that is considered largely effective against radiation-resistant tumours [13].

D. Immunotherapy

This is a biological process that employs certain therapeutic agents to stimulate or restore immune system functions, thereby assisting the body in fighting diseases. This therapy technique is frequently regarded as the "fourth modality" in cancer care and constitutes three forms of treatment: Cancer vaccines & other active immunotherapy vaccine e.g. human papillomavirus vaccine, monoclonal antibodies (e.g., trastuzumab), and non-specific adjuvant therapy and immunotherapy e.g., interferon or sargramostim [14]. The effectiveness of immunotherapy could be increased by individualized therapy with suitable antibody cocktails. Immunotherapy could be regarded as an alternative treatment procedure since it can get rid off of residual tumor cells regardless of their proliferative state [15]. The aim of immunotherapy for cancer is to surmount these barriers to result in an efficient anticancer immune response.

E. Hormone Therapy

Hormone therapy also referred to as hormonal therapy or endocrine therapy, which lessens or stops the growth of tumours that have hormone receptors or are hormone sensitive by disrupting the body's ability to produce hormones or by meddling with the response of the cancer cells to the effects of hormonal changes. Hormone treatment is ineffective or not responsive when tumours are hormone insensitive and do not have hormone receptors. This therapy technique works by inhibiting the action of hormones or replacing them and also stopping the growth of cancer cells [16]. The glands produce hormones which are then circulated via the bloodstream. Furthermore, certain cancers grow as a result of the presence of some hormones. When tests indicate that the tumors receptors, then treatments that involve the use of drugs, having radiation therapy or surgery are used to lessen the release of such hormones or stop them from being potent. Estrogen, which causes the growth of some breast cancers, is produced chiefly by the ovaries. Ovarian ablation is used to stop the ovaries from producing estrogen [1].

Hormone therapy with tamoxifen is usually administered to patients with early stage cancer that can be surgically excised and cancer that spread to other parts of the body (metastatic breast cancer). Hormonal treatment using the action of estrogens or tamoxifen on cells all over the body may result in the development of endometrial cancer. Female patients on tamoxifen are required to undergo pelvic exams annually to check for any signs of cancer. However, apart from menstrual bleeding, any other vaginal bleeding should be mentioned as soon as possible to the doctor. A luteinizing hormone-releasing hormone (LHRH) agonist is administered to premenopausal patients who are diagnosed to have a hormone receptor-positive breast cancer. LHRH agonists lessen the body's progesterone and estrogen. An aromatase inhibitor is administered to patients at the premenopausal stage with hormone receptor-positive breast cancer. These inhibitors (aromatase) reduce the body's estrogen by stopping the action of the enzyme called aromatase from converting androgen into estrogen. The kinds of aromatase inhibitors are anastrozole, letrozole, and exemestane [17], [18]. For the treatment of early localized breast cancer, surgery is used to remove cancer cell using adjuvant treatments of certain aromatase inhibitors instead of tamoxifen or after 2 to 3 years of tamoxifen use. The aromatase inhibitor is also in clinical trials to compare their use to hormone therapy with tamoxifen for metastatic breast cancer treatment. Anti-estrogen treatment such as fulvestrant or megestrol acetate is other kinds of hormone therapy [1].

F. Surgery

Surgery is aimed at removing as much of the tumor as possible. Different types exist but the one to be performed on a patient depends on his/her choice or as recommended by the physician, based on the medical history and cancer type. Surgery is done for several reasons such as to remove more of the cancer (breast-conserving surgery (BSC) or mastectomy), investigate the spread of cancer to the axillary lymph nodes, reconstruct the breast to restore its shape, and also to relieve symptoms of advanced cancer. BCS involves removing only part of the breast with cancer also called lumpectomy, quadrantectomy, partial mastectomy or segmental mastectomy. Mastectomy is aimed at removing the entire breast and sometimes including nearby tissues. Patients have the option to choose between BCS or mastectomy, advantages of BCS is, more of the breast tissue is reserved but in most cases, there is a need for additional radiotherapy. On the other hand, most mastectomies are less likely to include a further radiotherapy. Surgery is also done to remove nearby lymph nodes. This is done in order to investigate whether the cancer has spread to the lymph node. This is very important because it helps to figure out the stage of the cancer. After most surgeries, some patients consider having their breast rebuilt to restore its appearance (breast reconstruction). Even though surgery is not likely to cure breast cancer that has reach other parts of the body, it can still be helpful in slowing the spread of the cancer or to prevent or relieve symptoms of it [19].

II. Material and Methodology

A. PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluations)

The PROMETHEE technique is a multi-criteria decision making technique developed by [20], [21] which is based on mutual comparison of each alternative pair with regards to each selected criteria. This model is one of the easiest and most efficient methods in conception and application compared to other MCDM methods.

The advantages of PROMETHEE technique [22]:

- PROMETHEE is a user friendly outranking method.
- It has been successfully implemented to the real life planning problems.
- PROMETHEE I and PROMETHEE II give partial and total ranking of the alternatives respectively, while still satisfying simplicity.

The PROMETHEE method requires only two types of information: the information on the weights of the criteria considered and the decision-maker's preference function when comparing the contribution of the alternatives in terms of each separate criterion [23].

In PROMETHEE method, different preference functions are available in order to define different criteria. The preference function (P_j) denotes the difference between the evaluations obtained with two alternatives (a and $a_{t'}$) with regards to particular criterion, within a preference degree ranging from 0 to 1. There are six different types of preference functions that can be used to implement PROMETHEE method; usual function, U-shape function, V-shape function, level function, linear function and Gaussian function.

The basic steps of the PROMETHEE method [20], [24] are:

Step 1. For each criterion j, determine a specific preference function$p_j(d)$.

Step 2. Define the weights of each criterion$w_T = (w_1, w_2, \dots, w_k)$. At the discretion of the decision maker, each weights of criterion can be taken equally if only their importance is equal. And also normalization can be used for the weights; $\sum_{i=1}^{k} w_k = 1$.

Step 3. For all the alternatives,a_t, $a_{t'} \in$ A define the outranking relation π:

$$\pi(a_t, a_{t'}) = \sum_{k=1}^{K} w_k . \left[p_k\left(f_k(a_t) - f_k(a_{t'})\right)\right],$$
$$AXA \rightarrow [0,1]$$

Here π (a,b) denotes the preference index which is a measure for the intensity of preference of the decision maker for an alternative a_t in comparison with an alternative $a_{t'}$ while considering all criterion simultaneously.

Step 4. Determine the leaving and entering outranking flows as follows:

- Leaving (or positive) flow for the alternative a_t:

$$\Phi^+(a_t) = \frac{1}{n-1} \sum_{\substack{t'=1 \\ t' \neq t}}^{n} \pi(a_t, a_{t'})$$

- Entering (or negative) flow for the alternativea_t:

$$\Phi^-(a_t) = \frac{1}{n-1} \sum_{\substack{t'=1 \\ t' \neq t}}^{n} \pi(a_{t'}, a_t)$$

Where, n is the number of alternatives. Here, each alternative compared with (n-1) number of other alternatives. The leaving flow $\Phi^+(a_t)$ expresses the strength of alternative$a_t \in A$, while the entering flow $\Phi^-(a_t)$ denotes the weakness of alternatives, $a_t \in A$.

Via these outranking flows, the PROMETHEE I method can provide a partial pre-order of the alternatives and PROMETHEE II method can provide the complete pre-order based on net flow, however it doesn't give much information about the preference relations.

Step 5. Determine the partial pre-order on the alternatives of A according to following principle:

In PROMETHEE I alternative a_t is preferred to alternative $a_{t'}$ ($a_t P a_{t'}$) if it satisfies the one of the following conditions:

($a_t P a_{t'}$) if;

$$\begin{cases} \Phi^+(a_t) > \Phi^+(a_{t'}) and \Phi^-(a_t) < \Phi^-(a_{t'}) \\ \Phi^+(a_t) > \Phi^+(a_{t'}) and \Phi^-(a_t) = \Phi^-(a_{t'}) \\ \Phi^+(a_t) = \Phi^+(a_{t'}) and \Phi^-(a_t) < \Phi^-(a_{t,}a_{t'}) \end{cases}$$

When two alternatives a_t and $a_{t'}$ have the same leaving and entering flows, a_t is in different to $a_{t'}$ ($a_t I a_{t'}$):

$$(a_t I a_{t'}) \text{ if: } \Phi^+(a_t) = \Phi^+(a_{t'}) and \Phi^-(a_t) = \Phi^-(a_{t'}).$$

a_t is incomparable to $a_{t'}(a_t R a_{t'}$) if;

$$\begin{cases} \Phi^+(a_t) > \Phi^+(a_{t'}) and \Phi^-(a_t) > \Phi^-(a_{t'}) \\ \Phi^+(a_t) < \Phi^+(a_{t'}) and \Phi^-(a_t) < \Phi^-(a_{t'}) \end{cases}$$

Step 6. Determine the net outranking flow for each alternative

$$\Phi^{net}(a_t) = \Phi^+(a_t) - \Phi^-(a_t)$$

Via PROMETHEE II, the complete pre-order can be obtained by the net flow and defined by:

a_t is preferred to $a_{t'}$ ($a_t P a_{t'}$) if $\Phi^{net}(a_t) > \Phi^{net}(a_{t'})$

a is indifferent to $a_{t'}$ ($a_t I a_{t'}$) if $\Phi^{net}(a_t) = \Phi^{net}(a_{t'})$.

Basically the better alternative is the one having the higher $\Phi^{net}(a_t)$ value.

B. *Fuzzy PROMETHEE (F-PROMETHEE)*

There has been few research based on the approach of fuzzy PROMETHEE (F-PROMETHEE). Among the few researchers that have applied fuzzy PROMETHEE include [25]-[29]. In real life conditions, most times it is difficult to collect crisp data to define a problem properly and make an optimal decision. Using Fuzzy sets gives the decision maker the ability to define the problem under the vague condition which is more realistic.

The main aim of the Fuzzy PROMETHEE model was proposing a comparison between two fuzzy sets. Yager [30] found an index which is determined with the center of weight of the surface of the membership function to compare the fuzzy numbers. Yager defined the magnitude of a triangular fuzzy numbers $\tilde{F} = (N, a, b)$, which is equivalent to $\tilde{F} = (N - a, N, N + b)$, corresponding to center of triangle with the $YI = (3N - a + b)/3$ formula. In our F- PROMETHEE application we applied Yager index to compare the fuzzy numbers.

C. *Application*

First, we defined the importance of the parameters with the linguistic scale as seen in Table 1 and then we applied Yager index to obtain the weight for each criterion as seen in Table 2.

TABLE I. LINGUISTIC SCALE FOR IMPORTANCE

Linguistic scale for evaluation	Triangular fuzzy scale	Importance ratings of criterions
Very high (VH)	(0.75, 1, 1)	Cost of Machine, Cost of Treatment, Percentage of Survival
Important (H)	(0.50, 0.75, 1)	
Medium (M)	(0.25, 0.50, 0.75)	Treatment Time
Low (L)	(0, 0.25, 0.50)	
Very low(VL)	(0, 0, 0.25)	Comfortability

After we collect all the data for the alternatives, we applied them to Visual PROMETHEE Decision Lab program as shown in Table 2. We used the V-shape function for treatment time, linear function for cost of machine and cost of treatment and level preference function for comfortability and percentage of survival.

TABLE II. VISUAL PROMETHEE APPLICATION FOR THE CANCER TREATMENT ALTERNATIVES

Criteria	Treatment Time	Cost of Machine	Cost of Treatment	Comfortability	Survival Percentage
Unit	*weeks*	*$*	*$*	*y/n*	*%*
Preferences					
(min/max)	*min*	*min*	*min*	*max*	*max*
Weight	*0,50*	*0,92*	*0,92*	*0,08*	*0,92*
Preference Fn.	*V-shape*	*Linear*	*Linear*	*Level*	*Level*
Evaluations					
Chemotherapy	104	0	7470	Yes	70
Radiotherapy	6	3000000	5333	Yes	55
Hadron therapy	6	162500000	13833	Yes	97
Immunotherapy	104	0	27925	Yes	50
Surgery	2	0	32500	No	86
Hormone therapy	260	0	2256	Yes	69

III. RESULTS

Result from Table 3 shows that hadron therapy with the highest survival rate, short treatment time and non-invasiveness tops the list of alternatives and therefore, it will be more beneficial to the patient. The criteria for cost of machine were de-activated in getting the result as it does not benefit the patient.

Result from Table 4 shows that Surgery with the highest treatment cost will be more advantageous to the hospital.

The criteria for cost of treatment were de-activated while obtaining this ranking because it has no benefit on the hospital side.

Fig. 1 shows the positive and negative side of the Treatment Alternatives for each selected criteria. We used Decision Lab visual PROMETHEE program to have the result. This program is user friendly and the decision maker can change the criteria and also the weight for criterion easily and can compare the devices according to criteria they wish.

TABLE III. COMPLETE RANKING OF CANCER TREATMENT ALTERNATIVES IN TERMS OF PATIENT

Rank of alternatives **Negative outranking flow**	**Net flow**	**Positive outranking flow**
1 Hadron therapy	0,4931	0,5041 0,0110
2 Surgery	0,3741	0,4501 0,0760
3 Chemotherapy	-0,0446	0,2314 0,2760
4 Radiotherapy	-0,1152	0,2000 0,3152
5 Hormone therapy	-0,2446	0,1521 0,3967
6 Immunotherapy	-0,4628	0,0413 0,5041

TABLE IV. COMPLETE RANKING OF CANCER TREATMENT ALTERNATIVES IN TERMS OF HOSPITAL

Rank of alternatives **Negative outranking flow**	**Net flow**	**Positive outranking flow**
1 Surgery	0,5262	0,6022 0,0760
2 Hadron therapy	0,1129	0,5041 0,3912
3 Chemotherapy	0,1074	0,3835 0,2760
4 Hormone therapy	-0,0926	0,3041 0,3967
5 Immunotherapy	-0,3107	0,1934 0,5041
6 Radiotherapy	-0,3433	0,2760 0,6193

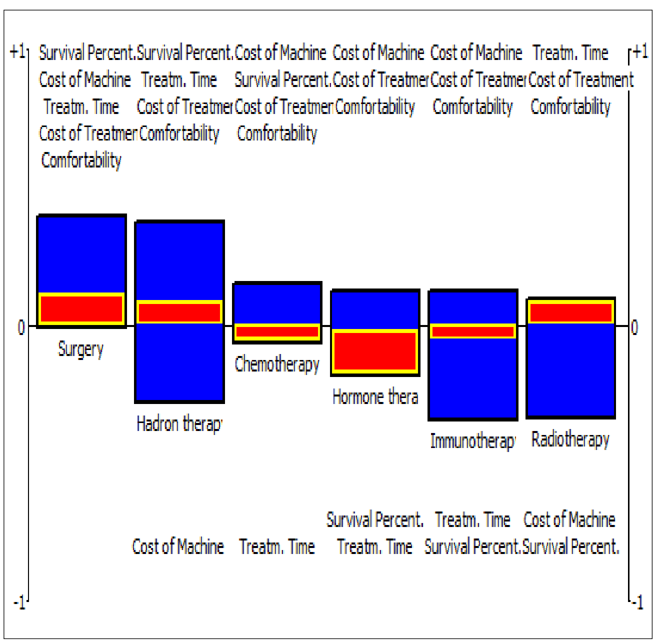

Fig. 1. PROMETHEE evaluation results.

IV. CONCLUSION

Using fuzzy PROMETHEE as a multi-criteria analysis technique, we were able to achieve good decision results by incorporating fuzzy input data. The fuzzy PROMETHEE method was applied on various cancer treatment alternatives. This study indicates that the proposed method simply and practically provides advanced alternative solutions to decision-making problems. The results of this ranking give the decision makers or organizations the ability to choose or improve their treatment procedures. The study can be improved by adding more criteria to the alternatives.

With the Fuzzy PROMETHEE technique, the problem of decision making for the fuzzy data is solved. This technique has proven to be very efficient in many fields when compared to other decision making techniques. The outcome of this study will benefit the patient, likewise the hospital management in making relevant decision as to managing the hospital or the patient. Other works have been done to compare nuclear imaging devices and image reconstruction techniques. This method can also be extended to other aspect of medical decision making.

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Cloud Computing Environment and Security Challenges: A Review

Muhammad Faheem Mushtaq[1], Urooj Akram[1], Irfan Khan[2], Sundas Naqeeb Khan[1], Asim Shahzad[1], Arif Ullah[1]

[1]Faculty of Computer Science and Information Technology,
Universiti Tun Hussein Onn Malaysia (UTHM),
Johor, Malaysia

[2]Directorate of Information Technology (IT),
Govt. Sadiq College Women University,
Bahawalpur, Pakistan

***Abstract*—Cloud computing exhibits a remarkable potential to offer cost-effective and more flexible services on-demand to the customers over the network. It dynamically increases the capabilities of the organization without training new people, investment in new infrastructure or licensing new software. Cloud computing has grown dramatically in the last few years due to the scalability of resources and appear as a fast-growing segment of the IT industry. The dynamic and scalable nature of cloud computing creates security challenges in their management by examining policy failure or malicious activity. In this paper, we examine the detailed design of cloud computing architecture in which deployment models, service models, cloud components, and cloud security are explored. Furthermore, this study identifies the security challenges in cloud computing during the transfer of data into the cloud and provides a viable solution to address the potential threats. The task of Trusted Third Party (TTP) is introducing that ensure the sufficient security characteristics in the cloud computing. The security solution using the cryptography is specifically as the Public Key Infrastructure (PKI) that operates with Single-Sign-On (SSO) and Lightweight Directory Access Protocol (LDAP) which ensure the integrity, confidentiality, availability, and authenticity involved in communications and data.**

***Keywords*—Cloud computing; deployment models; service models; cloud security; trusted third party; cryptography**

I. Introduction

Cloud computing extends the information technology capabilities by increasing the capacity and adds abilities dynamically without investing on large and expensive infrastructure, licensing software, or training new personals. Among the several benefits, cloud computing provides a more flexible way to access the storage and computation resources on demand. In the last few years, different business companies are increasingly understanding that by tapping the cloud resources and gaining fast access, they are able to reduce their initial business cost by paying only the resources they used rather than the need of potentially large investment (owning and maintenance) on infrastructure. Rapid deployment, cost reduction, and minimal investment are the major factors to employ cloud services that drive many companies [1]-[3]. Cloud computing is explained by National Institute of Standard and Technology (NIST). It is a model to enable convenient, ubiquitous and on-demand network access that is the configurable computing resources to shared resources which can be delivered and provisioned rapidly with minimum managerial interaction [4].

The cloud is the collection of virtualized and inter-connected computers that consists of parallel and distributed systems which can be dynamically presented and provisioned the computing resources based on some Service Level Agreements (SLA) that is established by the settlement between the customers and service provider [5]. The advantages of using cloud computing are offering infinite computing resources, low cost, security controls, hypervisor protection, rapid elasticity, high scalability and fault tolerant services with high performance. Many companies like Microsoft, Google, Amazon, IBM, etc. developed the cloud computing systems and provide a large amount of customers by enhancing their services [6]. Moreover, there are significant barriers to adopting cloud computing like security issue regarding the privacy, compliance and legal matters because it is relatively new computing model having a great deal of the uncertainty regarding the security of all levels such as host, network, data levels, and application can be accomplished [7]. The management of data and services is an important concern when the databases and application software are moves the cloud to the large data centers. It may arise many security challenges regarding the use of cloud computing includes the privacy and control, virtualization and accessibility vulnerabilities, credential and identity management, confidentiality, authentication of the respondent device and integrity [8], [9]. The increment in the adoption of cloud computing and the market maturity is growing steadily because the service providers ensure the complex security level, compliance and regulatory. In part this growth, the cloud services will deliver the increased flexibility and cost savings [10].

Cloud computing is authorized through the virtualization technology in which the host system operates an application referred as a hypervisor that generates one or more Virtual Machines (VM) and it faithfully simulates the physical computers. These simulations can be able to operate any software from operating system to the end-user application [11]. The number of physical devices lies in hardware level that includes hard drives, processors and network devices which are placed in the data centers. It is independent of the geographical location that is responsible for processing and storage as needed. The effective management of the servers is performed by the combination of the virtualization layer, software layer, and the management layer. Virtualization layer is utilized to provide the necessary cloud components of rapid elasticity, resource pooling, and location independent. Also, it is an essential element of cloud implementation. The ability to implement security rules and monitoring throughout the cloud is done by the management layer.

This research explains the overview of cloud computing architecture as: 1) cloud deployment models; 2) cloud service model; 3) cloud basic characteristics; 4) cloud security. Security concerns of different companies with the growing importance of cloud resources are taking into account when the data migrate to the modernize cloud systems, advances in business needs and the impact of services offered by the different organizations to increase the market. Moreover, this study focuses on to identifying the security issues and challenges in cloud computing that considers the threads, vulnerabilities, requirements, risks and discusses the security solutions and suggestion for the cloud computing. Also, discusses the Trusted Third Party (TTP) in the cloud computing environment by enabling the trust and cryptography that ensure the integrity, authenticity and confidentiality of data by addressing specific security vulnerabilities. The suggested solution to the horizontal level services which are available for the concerned entities that basically maintain trust to realize the security mesh. Public Key Infrastructure (PKI) operates with Single-Sign-On (SSO) and Lightweight Directory Access Protocol (LDAP) and is utilized to securely authenticate and identify the concerned entities.

The rest of the paper is organized as follows: Section 2 summarizes the detailed design of cloud computing architecture. Section 3 explains the security challenges of the Cloud computing. Section 4 describes the analysis and discussion based on the security challenges identified in the cloud computing environment. Section 5 presents the conclusions and future work of this research.

II. Cloud Computing Architecture

NIST is responsible for providing security in the cloud computing environment and developing standards and guidelines which shows a valuable contribution that offers a better understanding of cloud services and computing technologies [2], [12]. Cloud computing architecture summarize as the four deployment models: public cloud, private cloud, community cloud, and the hybrid cloud. The deployment models represent the way that the computing infrastructure delivers the cloud services can be employed. The three cloud service models or delivery models are available for the customer: Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS). There are different levels of security required for these service models in the cloud environment. The wide range of services considered in cloud basic characteristic layer that can be used all over the internet. The cloud service provider is corresponded to provide services, resource allocation management, and security. The architecture explains the five basic components which consist of services that are used in the cloud. The cloud security is the very important and complex task when the data transfer or shared resources to the cloud within the client-server architecture. The architecture of cloud computing is shown in Fig. 1 and details are discussed as follows:

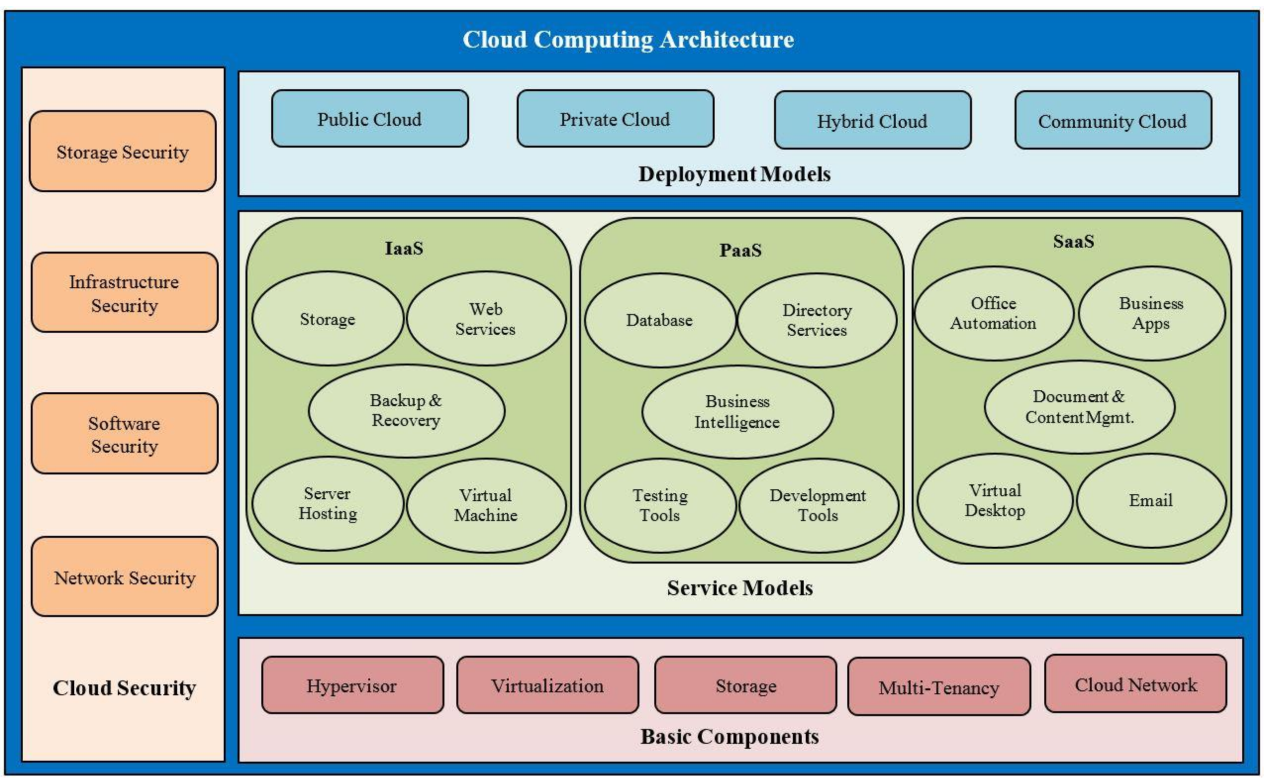

Fig. 1. Cloud computing architecture.

A. Cloud Deployment Models

The cloud computing model has three deployment models that can be particularly used to represent the cloud service models and it explains the nature and purpose of the cloud. The deployment models can be shown in Fig. 2 and classified as follows:

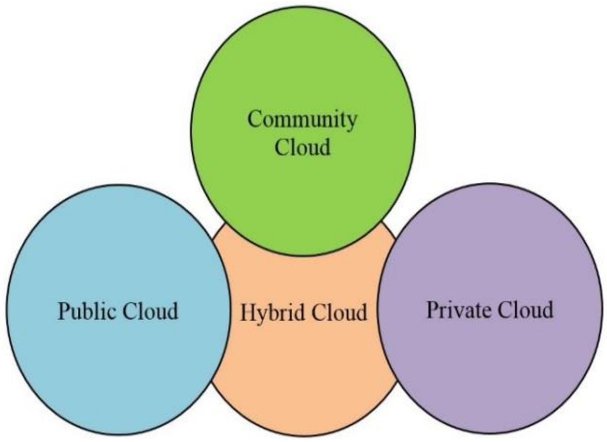

Fig. 2. Cloud deployment models.

1) Public Cloud: A public cloud represents the cloud hosting and owned by the service provider whereby the client and resource provider have service level agreement [4], [13]. Microsoft, Google, Amazon, VMware, IBM, Sun and Rackspace are some examples of cloud service provider. The plateform is designed in the form of generalized computing that holds the generic type of customer demand. The resources are made available to the public and easily accessible. Multiple entities are involved in operating public cloud and resource are public for the customers which makes them difficult to protect from malicious attacks. It contains some concerns over privacy, data access and security for customers because it is outside the firewall. It is less secure than the other deployment models and suited for a small and medium business that may not have to configure servers and purchase capital resources.

2) Private Cloud: The cloud infrastructure is managed and maintained by the single organization that compromises multiple customers. If any organization set up their own private cloud and recently create their own servers having physical hardware servers that put virtualization layer top on them then they would make resources available only internally. So, their application can deploy to their own physical control server, they don't need to go Microsoft or Amazon servers. They will set up their own infrastructure. It can ensure the physical security and more secure as compared to the public cloud because of its specific internal exposure. Private cloud is the only access to operate by the designated stakeholder and organization. However, the cost is significantly higher because expertise and training are needed for the server administrator, virtualization specialist, and network specialist. Virtual application and scalable resources provided by the cloud service provider are pooled together and it is available for customers to use and share. In private cloud, it is easier to address the relationship between the service provider and customer because the infrastructure operated and owned by the same organization [14]. It employs the capabilities of cloud management software to ensure reliable delivery service and integrity of the external resources.

3) Hybrid Cloud: Hybrid cloud is referred as the combination of two or more cloud deployment models that can be either public, private or community clouds which remains the unique entities but are bound together [15]. The importance of hybrid cloud usually offers extra resources when the high demand from the customer and for instance it is enabled to migrate some computation jobs from private to public cloud. It is well organized and allow different entities to access data over the internet because it offers more secure control of the applications and data. It provides a benefit over different deployment models and can be internally and externally hosted. Hybrid cloud gets more popularity and became a dominant model. The main reason is that it has the ability to take advantage of cost-saving, scalability in elasticity that public cloud may provide, allow control flexibility when it needed.

4) Community Cloud: Community cloud is referred as the organizations shared its cloud infrastructure among the customers having similar interest or concerns like a policy, the security requirements, mission and compliance consideration. We say that the several organizations or a third party are operated, controlled, shared and handled the resources of community cloud [16]. In case of the third party like Siemens have IT services and solutions that set up a media cloud for the media industry. It tends to be more rare and specialized. The cloud infrastructure of community cloud is shared and owned by different organizations such as research groups, together with work of companies and government organizations.

B. Cloud Service Models

Cloud computing architecture has a set of services which are used to access the configurable computing resources (applications, storage, servers, networks and services) on demand, dynamically scalable, virtualized and multi-tenant that offers a self-service over the internet. It provides the flexibility to handle the rapidly changing customer requirements and gives a reliable solution for customer demands. There are many service providers (Microsoft, Google, Amazon, Rackspace, etc.) that offer services to any of these models such as IaaS, PaaS and SaaS. The classification of cloud service models is important to figure out the particular service model that fulfills and accomplish its roles. The service model can be represented in Fig. 3 and the details are discussed as follows:

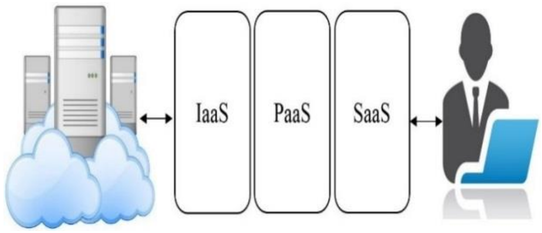

Fig. 3. Cloud service models.

1) Infrastructure as a Service (IaaS): IaaS offers the virtualized computing resources over the internet and deals with the hardware infrastructure such as servers, storage, processor, data center, network and various other infrastructure resources as a service where the user able to run and deploy arbitrary software. This infrastructure can significantly minimize initial cost of the companies to purchase computing hardware such as network devices, servers and processing power that allows the companies to major focus on core competencies instead of worrying regarding management and provisioning of infrastructure or own data centers [17]-[19]. The service providers for IaaS have hosted user applications and handle different jobs like resiliency planning and system maintenance backup. It has a major focus to improve the security in areas like VM monitor, intrusion detection, firewall and prevention (IPS/IDS). IasS model includes storage, web services, server hosting, VM, backup and recovery. The platform of IaaS provides the highly scalable resources which can be fixed on demand. It makes the plateform more suited for workloads having experimental, temporary or change unexpectedly. Furthermore, the characteristic includes the desktop virtualization, dynamic scaling, administrative tasks automation and policy-based services. The customer has control over deployed applications, storage, operating system and limited control are possible to select networking components like host firewall rather than the control or manage the cloud infrastructure. The well-known vendors for the IaaS are VMware, Hyper-V, Terremark, Amazon EC2, Dropbox, Sun Microsystems services and OpenStack to provide services to the customers and build their private or public cloud. Technically, the market of IaaS is relatively less movement of entry because it required a large investment to build the cloud infrastructure. The network services provided by public cloud in terms of Domain Name System (DNS) and load balancing. The DNS network service employs the domain name with IP addressing or hierarchical naming for the network identification and the load balancing offers a single access point to different servers that are working behind it. The load balancer used specific balancing techniques to distributes the network traffic between the multiple servers.

2) Platform as a service (PaaS): PaaS is the middleware of the service model and it provides the services in the form of programs, framework, integrated development environment, and development tools hosted on the server provider [20], [21]. It delivers a service to the developers that provides the software development lifecycle management (Planning, design, develop an application, deployment, testing and maintenance). The abilities offer to the customer or developers are deployed the developed applications onto the cloud infrastructure. The customer has only access to control the deployed applications and configurations of possible hosting environment instead of control the servers, storage, network and operating system. PaaS model worked similar to the IaaS but it offers the additional level of rented functionality and the customers using the services of PaaS model transfer more costs from hardware investment to the operational expense [22]. The vendor of PaaS offers some services for the application developers:

- The standards of the application based on developer's requirements.
- Logging, code instrumentation and reporting.
- Redundancy and security.
- A virtual development environment.
- The configuration of toolkits for the virtual development environment.
- Management interface and API.
- Multi-tenancy.
- Auto-provisioning and scalability of the underlying infrastructure.
- Built-in channel distribution for public application developer.

The well-known vendors for the PaaS model are: Microsoft Azure, Apprenda, Stackato, VMware, Google App Engine and NYSE Capital. PaaS model includes databases, directory services, business intelligence, testing and development tools. VM is employed in PaaS to act as a catalyst and it required to protect against the cloud malware attacks. It is important to include the valid authentication checks during the data transfer across the overall network channels and need to maintain the integrity of the applications. The security of PaaS can be compromised during the deployment of customer application or runtime of application and has challenges when underlying infrastructure security, lifecycle development and third-party relationship.

3) Software as a Service (SaaS): SaaS model is the collection of remotely hosted applications that are made available by the service provider for the customers on demand on the internet [4]. It has dominant cloud market as underlying technology that supports service oriented architecture and web services and still the market is growing rapidly. SaaS model offers the functionality of the business software to enterprise users at very low cost instead of providing facility to develop software or application. The vendors of SaaS models offer some core benefits are as follows:

- Easier administration.
- Universal accessibility.
- Easily collaboration.
- Software compatibility.
- Auto patch and updates management.

It allows the enterprises to get similar benefits of the internally operated commercially licensed software. However, still most of the enterprise users are not comfortable due to the deficiency in the visibility regarding their stored data in the cloud is secure or not [23]. Therefore, security concerns of enterprise addressing appear as the emerging challenge in the adoption of SaaS applications within the clouds. The security concerns about the application vulnerabilities, system availability and insider breaches that bring the loss of sensitive information or data. SaaS model includes virtual desktop, email, office automation, business apps, document and content management. The well-known vendors of SaaS service providers are the Salesforce and Google App that are the collection of remote computing services.

IaaS provides greater customer or tenant over the security than PaaS and SaaS. While the PaaS infrastructure provides better extensibility and customer control and the SaaS model is depending on integrated functionality with minimum customer control and extensibility. The security pressure of SaaS model varies on the cloud provider due to the degree of abstraction. Mostly large enterprise will like to create hybrid cloud environment with several private and public clouds having a possibility to mix community cloud into it. Some clouds will offer different enhancement in terms of security, performance, optimized pricing [24]. Furthermore, the optimized outcome is achieved by the enterprises through the deployment of an application with suitable cloud models. The well-known vendor used cloud service model with respective deployment models are shown in Table 1.

TABLE I. VENDER USED CLOUD DEPLOYMENT AND SERVICE MODELS

Service /Deployment Models	**Infrastructure as a Service (IaaS)**	**Platform as a Service (PaaS)**	**Software as a Service (SaaS)**
Public Cloud	Rackspace, Amazon EC2	VMware, Microsoft Azure, CloudFoundry.com, Google App Engine	Office 365, QuickBooks online, Salesforce.com
Private Cloud	OpenStack, Hyper-V, VMware, CloudStack	Stackato, Apprenda	Cisco WebEx
Hybrid Cloud	Rackspace, Custom	Cloud Foundry, Custom	Rackspace
Community Cloud	NYSE Capital	NYSE Capital	Salesforce

C. Cloud Basic Component

The cloud computing is deployed on the basic components and these components consist of wide range of services which can be used in the overall internet. In this study, some important components are considered as follows:

1) Hypervisor: The Hypervisor is referred to as Virtual Machine Monitor (VMM) or manager is computer hardware or firmware, software that allows to run and creates multiple virtual machines on single hardware host [25]. It is an important module of virtualization that monitors and manage the variety of Operating Systems (OS) which can share virtualized resources of hardware e.g. Windows, Linux and Mac OS that can run on the single physical system. The hypervisor can be classified into type 1 hypervisor and type 2 hypervisor. The type 1 hypervisor can directly operate in host system hardware such as Oracle VM server for x86, Microsoft Hyper-V and Xen. The type 2 hypervisor operates the guest operating from the host OS which offers virtualization service like memory management and I/O device support such as a Virtual box, VMware player, and VMware workstation. To determine the right selection of hypervisor that meets the need using the performance metrics such as guest memory, maximum host, a virtual processor supported and the CPU overhead. Moreover, to identify the hypervisor capabilities by verifying the guest OS on each hypervisor supports [25], [26].

2) Virtualization: Virtualization allows to share the physical instance resources by multiple customers or organizations. It helps to make one physical resource that is same as the multiple virtual resources [27]-[29]. Virtualization splits the services and resources from the underlying physical delivery environment. Virtualization is used to consolidate the resources (network resources, storage, processor and operating system) into a virtual environment that offers several benefits such as IT responsiveness and flexibility, reduce hardware cost by consolidation and workload optimization. However, it creates new challenges from attacker to secure the extra layer of VM due to more interconnection complexity and entry point increases using virtualization. It is important for the physical machine security because any problem may effect the other.

3) Storage: Customers use cloud storage over the network in which the data is backed up, managed and maintained remotely [9], [16]. The service provider major focus to improve the customer concerns regarding security capabilities such as authentication and encryption into their services. The vendors need to ensure that the data is secure, available and safe. Storage in cloud depends on the virtualized infrastructure with scalability, instant elasticity, metered resources, and accessible interfaces. The public cloud storage offers a multi-tenant environment of storage that is appropriate for the unstructured data. While the private cloud service offers dedicated storage environment that is protected behind customers or organization’s firewall. The hybrid cloud service provides more data deployment options and business flexibility because it mix the private and public cloud services. The benefits of using cloud storage are information management, time deployment, and total cost of ownership.

4) Multi-tenancy: Multi-tenancy environment contain a single instance of application software that can serve the multiple users or customers. The customers can only share applications or resources rather than to observe or share each other data in the execution environment [30]. Each customer is referred as the tenant and it may give the ability for customizing the application to some extent such as user interface color, but they are not authorized to customize the code of applications. SaaS service providers can run one part of the application with the corresponding database and offer web access or service to multiple tenants. The data of multiple tenants or customers is stored in the same database which effects the data leakage risk between this customer is high. The provider needs to ensure the security policies in which the data keep separate between the multiple tenants. The outcome of multi-tenancy is the optimal utilization of data storage and hardware mechanism. Multi-tenancy in cloud computing has broadened because it get advantages to romote access and virtualization for new service models.

5) Cloud Network: cloud networking is used to describe the access of network resources from the centralized service provider using the internet [31]. In this cloud, network and computing resources can be shared among the customers. The secure networking infrastructure is required for the efficiently manage and build the cloud storage. Cloud network needs an internet connection which is same with the virtual private network that allows the customer to securely access files, applications, printers, etc. The cloud network technology in the form of Software-Defined Networking (SDN) having a number of networking access devices and switches that can be deployed over the shared wide area.

D. Cloud Security

Cloud security is the set of control-based policies, compliance and technologies designed to deploy the protection of applications, data and infrastructure associated with the cloud. Cloud is used by more organizations and associated providers for operating data have become the priority to contract for proper security and potentially vulnerable areas. Cloud computing security is the major concerns when shared resources, access control, privacy and identity management needs [32]. Some of the concerns are discussed as follows:

- The data store in the cloud can be deliberately disclosed by the cloud providers, employees and its contractors.
- Cloud-based data may be incorrectly modified and vulnerable to delete (lost accidentally) by the service provider.
- In the public network, the data may be possibly accessible through the insecure APIs and protocols.
- The resources in the cloud are typically shared with different tenants that may be attacked.

Although, the security of data is in-fact challenging when data transfer to the cloud. This section briefly discusses the security concerns as follows:

1) Cloud Storage Security: The popularity and adoption of cloud storage is rising that produce many security challenges for the cloud providers as well as for the customers. IT experts to warn that every kind of technologies even virtual or physical, it contains inherent risks when using file-sharing applications and cloud storage. Customers store their data in the cloud have no longer owns the data because it will transfer through the third party that means the privacy setting of data is beyond the control of service provider or enterprises [33]. Customers need to ensure the quality of service and security of the data in the cloud. The security concerns about storage are data leakage, BYOD (Bring Your Own Data), snooping, cloud credentials and key management.

2) Cloud Infrastructure Security: Cloud computing enabling the distributed workforce and provides many benefits for the customers but it is essential to learn how to operate the cloud infrastructure that ensures and verify the secure deployment of services, storage of data, communication and safe operation through administration [21]. With the rapid adoption of cloud services, the concerns (privacy, security and reliability) have emerged as potential barriers. Information security professionals usually define the security guideline, rules and practice of cloud infrastructure of the organization at the application, host and network levels.

3) Software Security: The cloud provider required to protect their applications or software from internal and external thread throughout from design to production in their entire life cycle [34]. It is important to define the security process and policies about the software that enables the business instead of introducing other risk and it poses challenges for the customers and the cloud provider. Software security can be handled or defeat by implementing bugs, design flaws, buffer overflow, error handling agreements.

4) Cloud Network Security: A cloud service provider has the responsibility to allow the only valid network traffic and block all malicious traffic. Cloud providers are not shared the internal network infrastructure like the access routers and switches employ to connect cloud VMs to the provider network. The customer concerned on internal network attacks which include 1) leakage of confidential data; 2) unauthorized modification; and 3) denial of service or availability. Network security has concerns from both internal and external attacks because the attacker may legally authorize from another part of the network and attack can occur either physical or virtual network [34].

III. SECURITY CHALLENGES IN CLOUD COMPUTING

The applications of cloud services are operating in the cloud computing infrastructures by using the internet or internal network. The concept of trust in the organization can be referred as the customers assure the capabilities of the organization that it provides the required services reliably and accurately. Trust in cloud computing environment based on the selected cloud deployment models in which the applications are delegated and outsourced to the control of the owner. Trust has required an efficient and effective security policy in the traditional architecture that addressed the functional constraints and flows between them [35], [36]. External systems access the constraints that attack the programs which effect the access or control on the customer data. In cloud deployment models, the community or public clouds assigned control to the organization that owned the cloud infrastructure. When the public cloud-deployed, the control allows the owner of the infrastructure to strictly apply adequate security policy which ensures the appropriate security activities performed that reduces the threats and risks. Basically, the cloud security is associated to trust on computing and services employed by the infrastructure owner. The cloud infrastructure in private cloud is managed and operated within the premises of private organization in which no additional security challenges introduced, so the trust remained within the organization. It is believed that transfer of data or any association of organization or systems to the outside organization that opening a way to gain unauthorized access to the information resources [37].

Cloud computing allows the providers to run, deploy and develop applications that can be work rapidly (performance), scalability, maintainability and reliability without any concerns about the locations and properties of the underlying infrastructure. The consequences to avail these properties of the cloud when we store or transfer private data of different companies and get services from the cloud service providers by employing the internet that arises the privacy and security issues. For the purpose of securing cloud Information Systems (IS) which involve to identifying the challenges and threats that need to be addressed using the appropriate countermeasures implementation. Cloud computing infrastructure needs the assessment of risk in areas such as integrity, confidentiality, privacy, auditing, reliability and availability. Essentially, the security has major aspects of integrity, confidentiality and availability that are utilized in designing the adequate security system. These major security aspects are required to secure the data, hardware and software resources. Furthermore, discusses the Trusted Third Party (TTP) in the cloud computing environment through enabling trust and cryptography [38]. The cryptography is used to ensure the authenticity, confidentiality and integrity of data by trying to address the specific security vulnerabilities. Third parties or Cloud providers exhibit the trust of customers with specific quality, operational and ethical characteristics, and it comprises the minimal risk factor acknowledgment. TTP in the IS which is offering scalable end-to-end security services that depend on the standards and suitable in separate administrative domains, specialization sectors, and geographical areas. TTP in distributed cloud environment appears as the ideal security facilitator the customers or systems are belong to different domains without the knowledge or information of each other is needed to establish secure interactions. The security challenges of cloud computing infrastructure that can be considered in detail as follows:

A. Integrity

Data integrity in cloud computing is the preservation of data that is stored in cloud server to verify the data is not modified or lost by employing the services of the third party. Organizations can achieve more confidence to prevent system and data integrity from unauthorized access [39]. They provide such mechanisms having greater visibility to determine what or who may modify the system information or data that potentially affects their integrity. Authorization mechanism is utilized to determine the system what or which level of access to a specifically authorized customer should have to protected resources controlled through the system. Authorization is essential to ensure only the valid customers can access or interact with the data due to increasing the number of access points and customers in cloud computing environment.

The data integrity involves the three main entities: 1) a cloud storage provider to whom outsourced the data; 2) owner of data outsource his data; and 3) auditor who ensures the data integrity. The auditor may be the owner of data or he can assign responsibility to a third party [40]. The process of data integrity scheme defined as in two phases and is shown in Fig. 4. The preprocessing phase includes the preprocessed data and generated some additional metadata. After that outsources the data and metadata to the cloud storage provider. The verification phase includes the auditor send a challenge request to the cloud storage provider that generates possession proof with the data and metadata, and offers it to the auditor. The verification of proof done by the auditor that ensures the data integrity is intact.

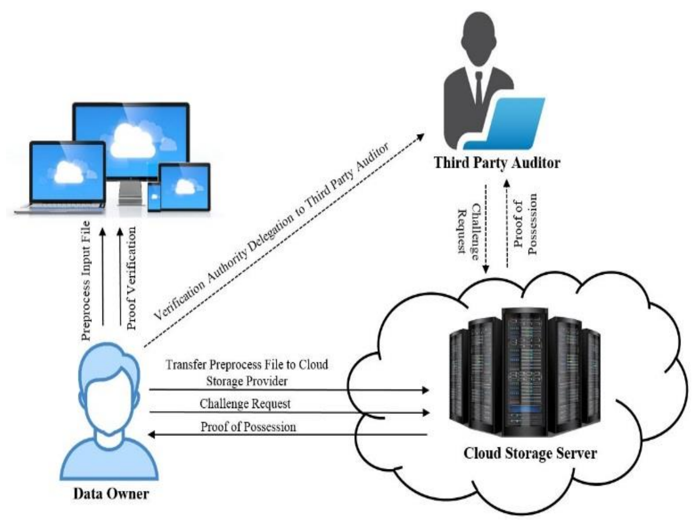

Fig. 4. Data integrity scheme.

The timely identification of any data deletion or corruption by using the data integrity scheme and takes necessary measures for the recovery of data. The data integrity scheme contains some design challenges in the cloud that are discussed as follows:

1) Computation eficiency: In data integrity scheme, the data can be preprocessed before outsource into the cloud storage server. The generation of metadata from original data similar to the cloud storage server. This processing creates overhead while performing may effect the computation efficiency. The preprocessing phase for small dataset does not matter the computation efficiency but it has a significant effect by using large datasets. In the server end, the computation cost of the proof of possession limits on how regularly the customer can verify or ensure the outsourced data integrity [41]. Data integrity scheme used primitives as metadata that also effects on the computation time.

2) Communication efficiency: The communication efficiency can be described three major aspects in the data integrity scheme: 1) data owner have challenge request for the proof of possession; 2) the challenge response from the cloud storage server for the verification of possession; and 3) overhead occur during the initial transfer of data along the metadata. The communication overhead in dynamic data that comprises the updates verification. The metadata utilized the primitives have effects on the communication cost. Algebraic signatures offer the communication efficiency by using the low network bandwidth during response time and challenge request [41]. The size of response and challenge is usually small by using the Hill cipher and offering the efficient communication.

3) Reduced disk I/O: The overhead in metadata access and block access for the generation of proof on the cloud storage server have derived the efficiency of disk I/O in the data integrity scheme. For the purpose of generating proof to access all blocks that impact on the efficiency of the data integrity scheme and scheme become impractical for employing large datasets. The overall efficiency of disk I/O can influence on following parameters [42], [43].

- The size of the disk in data integrity scheme either employ variable length block size or fixed. The size of the block is small, then the larger the blocks in the file that will influence the preprocessing time in metadata tags generation for all blocks.
- Due to the variable length of data/metadata that cannot be accessed directly a particular block index. It will impact on the disk I/O to increases the process of verification, so the time increases of generating a proof.
- The parameter challenge in a number of blocks has an influence on both the I/O cost and computation cost. The large blocks in a challenge that leads in proof generating time increased.

4) Security: The concerns while designing the data integrity schemes because they are vulnerable to different attacks [44]-[46]. The possible attacks against the schemes are discussed as follows:

- The tag forgery attack is possible through malicious cloud storage provider that try to hide the data damage of customers and avoid the auditing challenge.
- In the data deletion attack, the cloud storage provider may proceed the challenge through generating a legal proof of possession with the tags in which the original data may have entirely deleted.
- In the replace attack, the cloud storage provider may replace the data blocks of deleted or corrupted pair and respectively tags using another valid pair as the response of challenge with that deceive the verifier.
- The pollution attack defines the correct data is employed by the dishonest server in the generation of response against a challenge but it offers corrupted or useless blocks in repair phase.
- In the data leak attack, the extraction of stored data by the attacker during the proofing protocol with wiretapping technique.

The data integrity schemes may find difficult or fail to identify the data corruption timely that consequences an unrecoverable damage. The cloud provider ensured to maintain data accuracy and integrity. The cloud computing models explain numerous threats containing the sophisticated insider attack on the data attributes. Software integrity protects the software from the unauthorized modification by intentionally or unintentionally. Cloud service providers implementing a set of APIs or software interfaces used to help the customers to interact and manage the cloud services. Moreover, the cloud services security based on the interface's security because the unauthorized customer may gain control of them and change or delete the customer data [47], [48]. Administrator or software's owner is responsible to protect the software integrity. Network and hardware integrity is required to address the cloud provider and protect the underlying hardware from fabrication, modification and theft. Cloud service models (IaaS, PaaS and SaaS) are the fundamental task to keep the data integrity and usually offer massive data procession ability. The challenges associated with the data storage in the cloud when the solid-state disks (tapes or hard disk drives) capacity are increased and unable to keep pace with the growth of data. So, the vendors need to scale up the storage by increasing the space of solid-space disk (hard drives or tapes) that may consequence the high possibility of either the data corruption, data loss, disk failure or the node failure. Furthermore, the capacity of the solid-state disk is increasing more and more, while it may not get much faster in terms of data access.

B. Confidentiality

Confidentiality refers to keeping the customer's data secret in the cloud computing system and only the authorized customers or systems can able to access the data [49]. Cloud computing provides (e.g. applications and its infrastructures) are basically in the public clouds have more threads on the systems or applications are exposed as compare the hosted in the private data centers. So, it is the fundamental requirement to keep the customer data secret ever the increasing number of applications, customers and devices involved. The vendors of cloud computing are extensively adopted the two basic approaches such as cryptography and physical isolation to achieve the confidentiality [50]. The cloud computing provides services and data that are transmitted through the public network and it cannot achieve physical isolation. While virtual LAN and middle boxes network such as packet filters and firewall should be deployed to accomplish virtual physical isolation. VPN cubed released by CohesiveFT to offers a security boundary for the IT infrastructure although it is inside the single, multiple or hybrid cloud data center ecosystems. Vertica offers VPN and firewall to secure its database and deploys on the Amazon EC2. When the Amazon EC2 has provisioned the Vertica database and offers customers to full root access that helps customers can secure the systems. They create a VPN connection among the enterprise customers and Vertica to the cloud instance and firewall is set for the outside world. Confidentiality is also enhancing by encrypted the data before transfer into cloud storage and TC3 is successfully employed in this approach. Numerous concerns arises regarding the issues of application security and privacy, multi-tenancy, and data remanence [51].

1) Multi-Tenancy: Multi-tenancy refers to the characteristics of cloud resources that shared including the data, memory, networks and programs. Cloud computing is like the business model where the multiple customers can access same shared resources at the application level, host level, and network level. Multi-tenancy is similar to multi-tasking that shares some common processing resources like CPU and it present number of confidentiality and privacy threats.

2) Data Remanence: The data is represented in residual that can be unintentionally removed or erased due to the lack of hardware separation among different customers and virtual separation of the logical drives on a single cloud infrastructure, it may lead the unintentionally disclose the private data.

3) Application Security and Privacy: Data confidentiality is associated with the user authentication. To protect the customer's account from hackers is a large problem of controlling the access of the objects including software, devices and memory. The electronic authentication established the confidence of customer identities. If the customer used weak authentication to account can lead to an unauthorized access to the cloud. In the cloud computing environment, the customer needed to trust the applications offered by the organization that is handled and maintained the customer data in a secure manner. The possibilities of unauthorized access by the use of vulnerable applications or weak identification that create the issue of data privacy and confidentiality.

C. Availability

Availability in cloud computing including applications and its infrastructure is to ensure that the authorized customers can access the property of system at all time on demand. Cloud computing models (IaaS, PaaS and SaaS) allows its customers to access the services and applications from anyplace at any time. Vendors of cloud computing offers the cloud platform and infrastructure that is based on VM. The Amazon web services offer S3, EC2 that is based on VM called Skytap and Xen provides virtual lab management application depends on the hypervisor (Xen, VMware and Microsoft Hyper-V). For example, Xen virtual machine offered by Amazon is able to provide separated storage virtualization, memory virtualization, machine/CPU virtualization etc. where the large number of commodity PCs hosted. This is the reason the service providers can split resources (memory, capacity, storage, CPU cycle) on demand from Amazon based on usage expense in the form of each unit. Currently, the vendors of the cloud are offering platforms and infrastructures depend on the VM (Skytab, Amazon) provide the ability to filter and block the traffic based on port and IP address to secure systems but these services are not equal to the network security controls in mostly cloud enterprises.

Most cloud vendors (Google, Amazon) provide geographic redundancy in their cloud and hopefully allowing high availability on a single provider. The cloud system is capable to carry operations even in the security breaches possibilities or authorities misbehave [52]-[54]. Cloud service shows a heavy reliance on the network and infrastructure resources available at any time.

The information system design used to verify the identities of many systems that share mutual essential security requirements and determine the particular demands for information security and data protection. The multiple customer distributed environment suggests security challenges based on which level of user operates physical, virtual or application is shown in Table 2. The objectives of distributed system security are as follows:

- To ensure the data confidentiality among the participating systems.
- When add or remove resources on a physical level then maintain the exactly same security level.
- Make sure that there is no data leakage among different applications during the separation of processes and data in the cloud at the virtual level.
- To maintain or manage the integrity provided by the services such as correct operations and confidentiality.
- To provide the appropriate secure networks among the non- open systems world.
- To authenticate the different communicating customer's identities and if necessary the data delivery and origin for the purposes of banking to ensure the non-repudiation.
- To ensure the availability of data or systems communicated among the participating systems.
- The integrity of data or systems is maintained by preventing any modification or loss from unauthorized access between the participating systems communicated.

TABLE II. DISTRIBUTED SYSTEM SECURITY REQUIREMENT AND THREATS

Cloud Level	**Physical Level**	**Virtual Level**	**Application Level**
Cloud Services	Physical datacenter	IaaS, PaaS	SaaS
Users	Owner owns the cloud infrastructure that applies to the organization or customer	Developers deploy software on the infrastructure of the cloud that applies to the organization or customer	End user subscribes the services provides by cloud provider that applies to the organization or customer
Security Requirements	• Protection of network resources • Network protection • Legal use of cloud infrastructure • Security and reliability of hardware	• Virtual cloud Protection • Cloud control management security • Access control • Communication and application security • Security of data (transit/ rest/ remanence)	• Software security • Protection of data from exposure • Privacy in multi-tenant environment • Service availability • Communication protection • Access control
Security Threats	• Misuse of cloud infrastructure • Hardware modification or interruption or stealing • Network attacks • DDOS • Natural disasters • Connection flooding	• Network exposure • Session hijacking • Software interruption or modification • Connection flooding • Programming flaws • Impersonation • DDOS • Traffic flow analysis	• Privacy breach • Network exposure • Interception • Analysis of traffic flow • Data interruption • Session hijacking • Data modification at transit or rest • Impersonation

D. *Trusted Third Party (TTP)*

Trusted third party in cryptography helps to facilitate the interaction among the two parties and reviews all crucial operations among them. The cloud computing environment required the TTP services that exhibits to establish the essential trust level and offers an ideal solution to maintain the authenticity, integrity and confidentiality of communication and data. TTP can produce the trusted security domain with the specifically addresses the loss or missing of the traditional security boundary. It is an impartial organization which delivers the confidence of business by technical and commercial security features to electronic transactions [38]. TTP services are underwritten and offered along with the technical but also through the structural, financial and legal means. It is operationally linked with the chain of trust (certificate paths) for the purpose of providing a web trust that establishing the concept of Public Key Infrastructure (PKI). PKI offers legally acceptable and technically sound mean to implement data integrity, data confidentiality, authorization, strong authentication, and non-repudiation. In a distributed information system, PKI gets benefits from coupling through the directory that is a set of objects having same attributes that are organized in hierarchical and logical manner. Lightweight directory access protocol has become the vital protocol that supports to access PKI directory services for the Certificate Revocation List (CRL) and employed by web services for the authentication [55]. PKI is coupled with directory can be utilized to distribute: 1) certificate status information (CRL); 2) application certificate such as end-user certificate need to obtain using email before the transfer of encrypted message; and 3) private key, If the users do not use similar machine every day then the portability is needed in the environment. The directory contains the encrypted secret or private key are decrypted using the password given by customer at the remote workstation.

PKI are used with the Single-Sign-On (SSO) mechanism that can be ideal for cloud computing environment, where customers navigate among the abundance of the boundaries of cross-organization. In SSO environment, the user has not required to entering the password repeatedly to access multiple resources over the network. SSO is deployed with PKI that enhance the authentication and authorization process of the whole infrastructure between the evident technical issues due to it assured the sufficient level of the usability. The TTP can depend on following methods are defined as follows:

1) Client-Server Authentication: The certification authority needs to verify the entities or systems that are involved in interaction with the cloud computing environment which includes to certifying virtual servers, network devices, environment users, and physical infrastructure servers. The certification authority of PKI develops the required strong credentials for the virtual or physical entities that are involved in cloud and security domain are build with specific boundaries. The availability of strongest authentication process in distributed environments is the digital signature that is the combination of Ldap and SSO which ensure the user flexibility and mobility [56]. The authentication of customers is performed transparently and automatically to other devices or servers over the network by signing private key.

Cloud computing platform become enormous in which every service need secure authorization and authentication process. Among the conceptual boundaries of organization outsourced or own services become fuzzy, the adoption of required SSO solution is critical. Sibboleth is the middleware open source software that offers SSO within or across the organizational boundaries and trust on third party or cloud provider to share the information like user and named attributes [56]. Authorization process can be achieved after the successful authentication in which customer exchange his attribute without worried about the disclosure of personal information in the resource server.

2) Low or high-level confidentiality: Transmission of data across the network is a challenge due to its continuously rising the threats of data interruption or modification. Due to the deficiency in traditional physical connection, the complexity increases in cloud computing environment that it required not only protection toward cloud traffic but additionally among the cloud hosts. PKI allows by implementing SSL or IPSec protocol for the secure communications. IPSec enables to send or receive the protected packets such as UDP, TCP, ICMP, etc. without any modification and offers authenticity and confidentiality based on the requirement [38], [57]. IPSec customer can authenticate themselves with the PKI certificate to enchance scalability due to the earlier transmitted of trusted CA certificate. SSL protocol enables the interface among applications with end-to-end encryption and TCP/IP protocols offer encrypted communication channel and authentication between the client-server. Communication is needed to protect hosts, customers and host-to-host due to the unique characteristics of cloud computing. In this regard, SSL and IPSec are chosen based on the security requirement and diverse needs.

3) Cryptographic data separation: The protection of sensitive data is essential in the cloud computing environment that established as a crucial factor in the successful SaaS model deployment. Cryptographic separating of the data, computations and processes are hidden or secret using the encryption technique that appears intangible for outsiders and maintains the confidentiality, integrity and privacy of data. Symmetric and asymmetric cryptographic techniques are combined (referred as hybrid cryptography) that can provide the efficiency and security of data [58], [59].

IV. Analysis and Discussion

In this section, discusses the suggested security solution of the challenges faced in the adoption of cloud computing environment that influence the customers to release security burden with trusting a third party. This study observed that the concerns of trust, security and privacy highlighted by many cloud providers and customers. The deployment of security strategies in the cloud environment to achieve integrity, confidentiality and availability of data or systems that adopts to change the relationship between the cloud provider and the customers. A trust-worthy access control infrastructure is needed to avoid any unauthorized access to the shared resources. Trust required operating in each layer of the cloud service models (IaaS, SaaS, PaaS) and it needs to ensure the security at the technical, legal, procedural and operational level to allow secure communication. Trust certificate establishes an entities credentials, identity and responsibilities and serves as the electronic authentication. The required trust is provided by TTP to ensure the identity of communicating parties or entities and examined to adhere the strict policies and requirements. The end user is needed to utilize electronic certificate for authentication with the cloud service and validating the access rights to avail the particular resources. The secure SSL connection is created by the combination of the personal digital certificate with the service provider certificate (IaaS or PaaS), so the cloud infrastructure guarantees or ensures the security of encrypting exchange data.

A number of services are hosted by the cloud infrastructure, so the several applications are transferred to the virtual server and each required their own certificate for the SSL communication. The application provider needs his own certificate for the encryption and decryption of application data and authentication for secure communications in the cloud. A digital certificate is used by the owner of hardware infrastructure to communicate security among the virtual servers and devices. Key management is the challenging issue in cloud infrastructure as the virtualization services are concealing the representation of the location of physical key storage and disable the traditional protection mechanism. In this case, the key protection by deploying the temper proof devices such as customer smart card that is coupled with hardware security module as a component of virtual deployment. The solution for this problem is addressed with cryptography by PKI that provides and ensures the integrity, confidentiality and authentication of the communication and data involved. In the cloud environment, TTP ensures the specific security characteristics. While it realizes a trust mesh among the entities involved forming cloud federations. The solution of the problem to the horizontal level services which are available for the concerned entities that basically maintain trust to realize the security mesh. This approach utilized the SSO technology, LDAP directories, and PKI cryptography to securely authenticate and identify the concerned entities. The TTP is based on the following methods: 1) client-server authentication; 2) low or high-level confidentiality; and 3) cryptography separation of data.

The ability of PKI is to effectively address the problems of security issues in key management. System and network performance is the important factor in the centralized system. Availability in cloud infrastructure will increase the network demand and quality of service offers the key issues during host-to-host communication, it required additional encryption process to handle the deficiency. The flexibility of using cloud infrastructure in the context of demand on CPU controls the systems from overhead and accelerates encryption and decryption technique.

V. Conclusion and Future Work

Cloud computing is the emerging technology that brings many benefits for its customers, organizations and companies. However, despite bringing several advantages, it raises many security challenges in the adoption of cloud. We explained the detail design of cloud computing architecture in which deployment models, service models, cloud components, and cloud security are explored. This research attempted to present many security challenges, threats, attacks and vulnerabilities in the systems or data during transfer to the cloud. The countermeasure of the security threats will assist the organizations to continue the cost-benefit analysis and to encourage them to transfer into the cloud. In this paper, we discussed the generic design principles of cloud computing environment that stem from the necessary control the relevant threads and vulnerabilities. Cloud computing security requires a fundamental point of view from where it is based on mitigating protection and trust to the TTP. Most of the identified threats can be address by the combination of SSO, LDAP and PKI in cloud computing that is dealing with the authenticity, availability, integrity and confidentiality in communication or data. This research can be further analyzed in future to improve the quality and availability of services that brings the attraction of the customers toward the deployment of cloud computing and develop more customer's trust to the TTP. Also, developing a framework of complete security and privacy trust evaluation management system is a part of cloud computing services which satisfies the security demands.

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Verifying Weak Probabilistic Noninterference

Ali A. Noroozi
Department of Computer Science
University of Tabriz
Tabriz, Iran

Ayaz Isazadeh
Department of Computer Science
University of Tabriz
Tabriz, Iran

Jaber Karimpour
Department of Computer Science
University of Tabriz
Tabriz, Iran

Shahriar Lotfi
Department of Computer Science
University of Tabriz
Tabriz, Iran

***Abstract*—Weak probabilistic noninterference is a security property for enforcing confidentiality in multi-threaded programs. It aims to guarantee secure flow of information in the program and ensure that sensitive information does not leak to attackers. In this paper, the problem of verifying weak probabilistic noninterference by leveraging formal methods, in particular algorithmic verification, is discussed. Behavior of multi-threaded programs is modeled using probabilistic Kripke structures and formalize weak probabilistic noninterference in terms of these structures. Then, a verification algorithm is proposed to check weak probabilistic noninterference. The algorithm uses an abstraction technique to compute quotient space of the program with respect to an equivalence relation called weak probabilistic bisimulation and does a simple check to decide whether the security property is satisfied or not. The progress made is demonstrated by a real-world case study. It is expected that the proposed approach constitutes a significant step towards more widely applicable secure information flow analysis.**

***Keywords*—Confidentiality; secure information flow; noninterference; algorithmic verification; bisimulation**

I. INTRODUCTION

A. Motivation

In information security, a *confidentiality policy* prevents the unauthorized disclosure of information. Confidentiality policies are defined in terms of confidentiality mechanisms, which are approaches to enforce the policies [1]. Cryptography and access control are examples of confidentiality mechanisms. But they do not restrict the flow of information inside a program. For example, when an android application grants permission to access contacts, there is no cryptography or access control mechanism to verify legal use of the contacts by the application. This is where secure information flow comes to the rescue.

Secure information flow controls the way information flows throughout a program. Information flow properties are designed to prevent the information from flowing to an unauthorized user, i.e., attacker or low-observer [2]. Typically, it is supposed that there are two security levels, *high* (*H*) and *low* (*L*), corresponding to higher and lower confidentiality for program variables respectively. An information flow property is defined in such a way that it prevents data in *H* from flowing to *L*. More complex hierarchies of security levels can be defined via a security structure [3]. Information flow properties are of paramount significance for guaranteeing confidentiality of data. Because of this, it is desirable to establish an automatic and efficient verification approach for secure information flow.

B. Background

In most of researches done on secure information flow, a security property specifying the confidentiality policy is formally defined and then a verification method is proposed to check the property. *Noninterference* [4] is a long-established information flow property, stipulating that high data may not interfere with low data. The absence of interference requires *indistinguishability* of program behavior, as secret inputs are varied.

Probabilistic noninterference is a widely-used security property for multi-threaded programs, proposed by Volpano and Smith [5], and extended by Sabelfeld and Sands [6]. It is a timing- and probabilistic-sensitive property, defined over a simple imperative language with dynamic thread creation. Sabelfeld and Sands define a timing-sensitive partial probabilistic bisimulation to characterize indistinguishability of the executions of the program. The intuition is that low-equivalent states must produce executions that run in lock-step, affect the shared memory in the same way, and the probability of stepping to the states from the same equivalence class be the same [6].

Smith [7] shows that probabilistic bisimulation is too strict regarding time. To address this problem, Smith defines probabilistic noninterference in terms of *weak probabilistic bisimulation*, allowing probabilistic systems to be regarded as equivalent when they do not run at the same time. The resultant property is called *weak probabilistic noninterference*, which requires low-equivalent states to produce executions that visit the same sequence of equivalence classes, but some executions may remain in a class longer that the other executions.

Verifying secure information flow is mostly done via *information flow type systems*. A type system is a formal system of type inference rules for reasoning about properties of programming languages [8]. In information flow type systems, the property of interest is a property of secure information flow, e.g., probabilistic noninterference. Many information flow type systems have been proposed to enforce probabilistic noninterference. Sabelfeld and Sands [6] define a type system to verify probabilistic noninterference. Smith [9] proposes a new type system to enforce probabilistic noninterference for multi-threaded programs running under a uniform probabilistic scheduler. In [7], Smith applies weak probabilistic bisimulation to prove that the type system proposed by him in [9] guarantees the probabilistic noninterference.

Type systems are automated and compositional, but they are not extensible, as each new feature added to the programming language, or variation of the information flow property requires a redefinition of the type system and its soundness proof [10]. Consequently, *algorithmic verification* has been favored recently, which is the application of rigorous, mathematically sound, and fully automatic techniques to the analysis of systems. These techniques are more flexible than type systems, and give a precise and efficient mechanism to verify a variety of security properties, without the need to prove soundness repeatedly [11].

Algorithmic verification techniques have been mostly developed for trace properties, which describe single executions of programs. But, most security properties, including weak probabilistic noninterference, are *2-safety* properties. 2-safety properties predicate over two executions of a program and consequently, verification requires establishing relationships between two different executions [12]. For example, weak probabilistic noninterference is not a property of individual executions and hence not a trace property, because whether an execution is allowed by the property depends on whether another execution is also allowed. 2-safety properties are an important subset of *relational* properties, which describe multiple executions of one or more programs [13]. As most classical verification techniques are not adequate to reason about relational properties, recently, many new techniques have been developed for secure information flow [12], [14]-[19], but none for weak probabilistic noninterference.

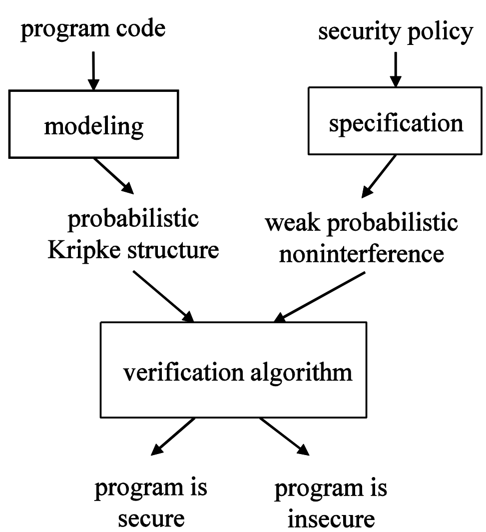

Fig. 1. Components of the proposed approach.

C. Foreground

In this paper, an algorithm is developed to verify weak probabilistic noninterference for multi-threaded programs running under an arbitrary scheduler. The program to be verified is modeled by a probabilistic state transition system, called probabilistic Kripke structure. Weak probabilistic noninterference is formally defined in terms of semantics of the probabilistic Kripke structure. In the proposed analysis, a program satisfies weak probabilistic noninterference, if and only if all executions with low-equivalent initial states visit the same sequence of equivalent classes with respect to weak probabilistic bisimulation. The verification algorithm computes the quotient space, i.e., the set of all equivalence classes of the probabilistic Kripke structure and does a simple check to decide the satisfaction of the security property. The quotient space is an abstraction of the concrete model of a program and allows obtaining enormous state-space reductions, possibly avoiding sate explosion problem. It is shown that the proposed verification algorithm runs in polynomial time. A case study is provided to show the feasibility of the verification algorithm. Fig. 1 gives a clear picture of the proposed approach.

D. Structure of the Paper

The paper starts by an informal overview of the approach in Section II. The program model assumed throughout the paper is presented in Section III. Weak probabilistic noninterference is defined in Section IV, using weak probabilistic bisimulation. The verification algorithm, time complexity, and application of the algorithm to a case study are addressed in Section V. Discussing related work and comparisons are done in Section VI. Finally, Section VII concludes the paper and discusses some future work.

II. Overview of Approach

In this section, a tour of the proposed work is given. To build intuition for the proposed approach, the key idea is illustrated using an example.

For clarity, some informal definitions are discussed. Suppose an *attacker* has full knowledge of source code of a multi-threaded program, can choose a scheduler for its execution, and observe the program behavior under the chosen scheduler. By observing behavior, we mean the attacker can see values of *public* variables *during* the program execution. For example, she can print public values. If the attacker can infer information about secret (high) values of the program by observing public (low) values, the program is said to have a *leak (or channel)*. Depending on the ability of the attacker, programs may have different leaks; e.g., explicit, implicit, or probabilistic leaks. Explicit leaks occur when a high value is assigned to a low variable; e.g., `l:=h`, assuming `l` is a low variable and `h` is a high variable. Implicit flows happen because of the control structure of a program; e.g., `if h=1 then l:=1 else l:=0`. Probabilistic leaks occur as a result of probabilistic behavior of the program. An example of this leak will be given in the following.

Secure information flow to the rescue. Secure information flow analysis aims to detect and consequently avoid information leaks in a program. Usually, it involves three main steps: 1) The program behavior is defined using a program model; 2) The absence of leaks is defined using a security property; 3) A verification technique is developed to check the satisfaction ability of the property in the given program. In this paper, probabilistic Kripke structure (definition 1) is used to model the program behavior. Weak probabilistic noninterference (definition 8) of Smith [7] is reformulated in terms of the program model, and finally an algorithmic verification technique (Algorithm 1) is developed to check the property.

A program satisfies weak probabilistic noninterference, if each *pair* of program executions with *low-equivalent* initial values are *indistinguishable*. Smith defines indistinguishability via weak probabilistic bisimulation $\approx_p$ (definition 6), an equivalence relation relating executions that change low values in the *same order*, with the *same probability*. Thus, an attacker observing pairs of weak probabilistic bisimilar executions with low-equivalent initial values (and probably different initial high values), will not be able to distinguish these executions and consequently infer secret information.

For further clarity, consider the following example program:

l:=0; l:=h mod 2; (l:=h || (l:=0 || l:=1))

Where, `||` is the parallel operator and `h` can have values 0 or 1. Suppose a uniform scheduler S , where each statement of `||` is chosen with probability ½ . Then, final value of `l` will reveal h with probability of ¾ . This is a probabilistic leak. Fully probabilistic Kripke structure of the program $\mathrm{K_S}$ induced by the uniform scheduler is shown in Fig. 2. In this figure, nodes and edges represent states and transitions between states of the program, respectively. Edge labels show transition probabilities. Probability of transitions without a label is 1. Each state label shows the value of `l` in the corresponding state. The set of states, initial states, and executions are $S=\{s_0,s_1,\dots,s_{24}\}$, $\mathrm{I}=\{s_0\}$, and $Execs(\mathrm{K_S})=\{\sigma_0=s_0s_1s_2s_3s_4^{\omega},\sigma_1=s_0s_1s_2s_5s_6^{\omega},\dots,\sigma_7=s_0s_{13}s_{22}s_{23}s_{24}^{\omega}\}$, respectively.

Verification. According to weak probabilistic noninterference, executions with low-equivalent initial values should be weak probabilistic bisimilar. A key idea of the proposed technique is to break down the executions of the program into various *groups*, depending on low-equivalency of initial states, and in each group check $\approx_p$ between the executions. To do this, the initial states are partitioned, based on the low-equivalence relation, into $\mathrm{IB}_0,\dots,\mathrm{IB}_m$ so that $\approx_p$ can be checked between every $\sigma\in Execs(\mathrm{IB}_i)$.

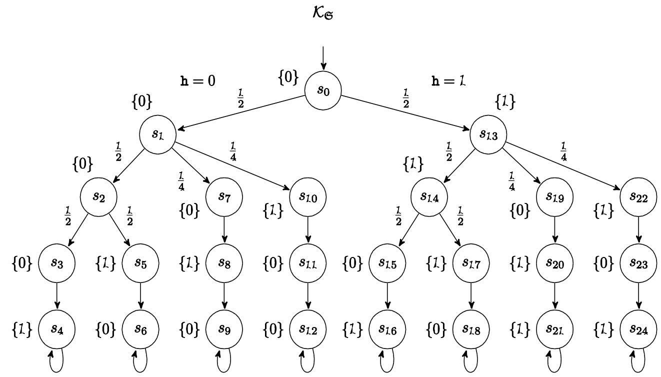

Fig. 2. Model of the example program.

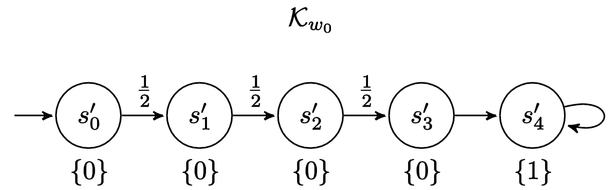

Fig. 3. Witness execution for the example program.

Another key idea is that a witness execution w_i is chosen for each group of executions $Execs(\mathrm{IB}_i)$ and check $\approx_p$ between w_i and every $\sigma\in Execs(\mathrm{IB}_i)$. According to lemma 1 (Section V), w_i and σ have relation $\approx_p$ if and only if their initial states, i.e., $w_i[0]$ and $\sigma[0]$ have relation $\approx_p$. This means the set of equivalence classes (quotient space) of combination of $Execs(\mathrm{IB}_i)$ and w_i with respect to $\approx_p$ can be computed. Then, $w_i[0]$ and every $\sigma[0]$ should belong to the same equivalence class. If not, then the program does not satisfy weak probabilistic noninterference and is not secure.

Back to the example, the set of initial states are partitioned. As there is only 1 initial state, just 1 block is obtained: $\mathrm{IB}_0=\{s_0\}$. The execution $s_0s_1s_2s_3s_4^{\omega}$ is chosen as the witness and the state names are renamed, so that they are not confused with the states of $\mathrm{K_S}$. Thus, the witness execution is $w_0=s_0^{'}s_1^{'}s_2^{'}s_3^{'}s_4^{'\omega}$ (Fig. 3). The quotient space of the combination of $\mathrm{K_S}$ and w_0 is computed. The quotient space has 12 blocks: $\{s_0\}$, $\{s_1\}$, $\{s_{13}\}$, $\{s_2\}$, $\{s_7\}$, $\{s_5,s_8,s_{10},s_{17}\}$, $\{s_{14}\}$, $\{s_3,s_3^{'},s_{15},s_{19},s_{23}\}$, $\{s_{22}\}$, $\{s_6,s_9,s_{11},s_{12},s_{18}\}$, $\{s_4,s_4^{'},s_{16},s_{20},s_{21},s_{24}\}$, $\{s_0^{'},s_1^{'},s_2^{'},\}$. As s_0 and $s_0^{'}$ do not belong to the same equivalence class, the verification algorithm returns insecure. This is what was expected.

III. Program Model

In this section, the program model assumed throughout the paper is introduced. Furthermore, some basic concepts concerning probability distributions, partitions, and equivalences are recalled.

A *probability distribution* μ over a set X is a function $\mu : X \to [0,1]$, such that $\sum_{x \in X} \mu(x) = 1$. The set of all probability distributions over X is denoted by $\mathrm{D}(X)$. The support of a probability distribution $\mu \in \mathrm{D}(X)$ is the set of all elements with a positive probability, i.e., $supp(\mu) = \{x \in X \mid \mu(x) > 0\}$.

A *partition* of a finite set S of states is a set $\{B_1, B_2, \ldots, B_n\}$ such that $B_i \neq \varnothing$, $\bigcup_i B_i = S$, and B_i are pairwise disjoint. B_i are called *blocks*. An equivalence relation R on S partitions S into the set of *equivalence classes*. The equivalence class of $s \in S$ w.r.t. R, denoted $[s]_R$, is defined as $[s]_R = \{s' \mid (s, s') \in R\}$. The set of equivalence classes of S w.r.t. R is called *quotient space*, denoted S / R.

Probabilistic Kripke structures are used to model operational semantics of probabilistic programs. Probabilistic Kripke structures are state transition systems that permit both probabilistic and nondeterministic choices. A state of a probabilistic Kripke structure indicates the current value of all low variables (shared memory of the multi-threaded program) together with the current value of the program counter that indicates the next program statement to be executed.

Definition 1 (Probabilistic Kripke Structure (PKS)): A *probabilistic Kripke structure* is a tuple $\mathrm{K} = (S, \to, \zeta, AP, La)$ where,

- S is a set of states,
- $\to \subseteq S \times \mathrm{D}(S)$ is a transition relation,
- ζ is an initial distribution such that $\sum_{s \in S} \zeta(s) = 1$,
- AP is a set of atomic propositions,
- $La : S \to 2^{AP}$ is a labeling function.

Here, atomic propositions are possible values of the low variables. K is called *finite* if S and AP are finite. The set I containing states s with $\zeta(s) > 0$ is considered as the set of *initial states*. The set of successor distributions of a state s is defined as $Post_D(s) = \{\mu \in \mathrm{D}(S) \mid s \to \mu\}$. The set of successor states of a state s is defined as $Post(s) = \cup_{\mu \in Post_D(s)} supp(\mu)$. A state s is called *terminal* if $Post(s) = \varnothing$.

Executions in a PKS K are alternating sequences of states that may arise by resolving both nondeterministic and probabilistic choices in K. More precisely, a finite *execution fragment* $\hat{\sigma}$ of K is a finite state sequence $s_0 s_1 \ldots s_n$ such that $s_i \in Post(s_{i-1})$ for all $0 < i \le n$. An *infinite* execution fragment σ is an infinite state sequence $s_0 s_1 s_2 \ldots$ such that $s_i \in Post(s_{i-1})$ for all $0 < i$. An execution fragment is called *initial* if it starts in an initial state, i.e., if $\zeta(s_0) > 0$. An *execution* of K is either an initial finite execution fragment that ends in a terminal state, or an initial infinite execution fragment.

Let $\sigma = s_0 s_1 s_2 \ldots$ be an execution and let $\sigma[0] = s_0$. $Execs(s)$ denotes the set of executions starting in s and $Execs(\mathrm{K})$ the set of executions of the initial states of K: $Execs(\mathrm{K}) = \bigcup_{s \in \mathrm{I}} Execs(s)$. Let $\mathrm{I}' \subseteq \mathrm{I}$; Then, $Execs(\mathrm{I}') = \bigcup_{s \in \mathrm{I}'} Execs(s)$.

A PKS with no non-determinism is called a fully probabilistic Kripke structure.

Definition 2 (Fully Probabilistic Kripke Structure (FPKS)): A PKS is called *fully probabilistic* if for each state there is at most one outgoing transition, i.e., $\forall s \in S : s \to \mu$ and $s \to \mu'$ implies $\mu = \mu'$.

FPKSs are state transition systems with probability distributions for transitions of each state. That is, the next state is chosen probabilistically, not non-deterministically. In the definition of FPKS, for convenience the transition relation $\to$ is replaced with a transition probability function $\mathbf{P} : S \times S \to [0,1]$. The function $\mathbf{P}$ determines for each state s the probability $\mathbf{P}(s, s')$ of a single transition from s to s'. The probability $\mathbf{P}(s, T)$ is defined as the probability of moving from s to some state $t \in T$ in a single step, i.e., $\mathbf{P}(s, T) = \sum_{t \in T} \mathbf{P}(s, t)$.

Reasoning about probabilities of sets of executions of a PKS relies on the resolution of the possible non-determinism in the PKS. This resolution is performed by a *scheduler*. A scheduler takes a finite execution (history of computation) as input and chooses the next transition to execute. Let $S^+ = \{s_1 s_2 \ldots s_k \mid k > 0 \text{ and each } s_i \in S\}$. Formally,

Definition 3 (Scheduler): Let $\mathrm{K} = (S, \to, \zeta, AP, La)$ be a PKS. A *scheduler* for K is a function $\mathrm{U} : S^+ \to \mathrm{D}(S)$, such that for all $\sigma = s_0 s_1 \ldots s_n \in S^+$, $\mathrm{U}(\sigma) \in Post_D(s_n)$.

A *finite-memory* scheduler denotes a scheduler that can be described by a deterministic finite automaton (DFA). Formally,

Definition 4 (Finite-memory scheduler): Let K be a PKS with state space S. A *finite-memory scheduler* S for K is a tuple $\mathsf{S} = (Q, \Delta, de, st)$ where,

- Q is a finite set of *modes*,
- $\Delta : Q \times S \to Q$ is a transition function,

- $de: Q \times S \to \mathrm{D}(S)$ is a decision function that selects the next transition $de(q,s)$ for any mode $q \in Q$ and state s of K ,
- $st: S \to Q$ is a function that selects a starting mode for state s of K .

The behavior of a PKS $\mathrm{K} = (S, \to, \zeta, AP, La)$ under a finite-memory scheduler $\mathsf{S} = (Q, \Delta, de, st)$ is as follows. At the beginning, an initial state s_0 is randomly chosen such that $\zeta(s_0) > 0$ and the DFA S is initialized to the mode $q_0 = st(s_0) \in Q$. Assuming that K is in state s and the current mode of S is q, the next transition is given by the decision function, i.e., $de(q,s) = \mu \in Post_D(s)$. Subsequently, the PKS randomly moves to the next state according to the distribution μ, while S changes mode to $\Delta(q,s)$.

As all nondeterministic choices in a PKS K are resolved by a finite-memory scheduler S , a fully probabilistic Kripke structure K_{S} is induced. The states in K_{S} are pair $< s, q >$ where s is a state in K and q a mode of S . Formally,

Definition 5: Let $\mathrm{K} = (S, \to, s_0, Var, La_{\mathrm{h}}, La_{\mathrm{l}})$ be a PKS and $\mathsf{S} = (Q, \Delta, de, st)$ be a finite-memory scheduler on K . **The FPKS of** K **induced by** S is given by

$$\mathrm{K}_{\mathsf{S}} = (S \times Q, \mathbf{P}, s_0, Var, La_{\mathrm{h}}^{'}, La_{\mathrm{l}}^{'})$$

Where, $La_{\mathrm{h}}^{'}(< s, q >) = La_{\mathrm{h}}(s)$, $La_{\mathrm{l}}^{'}(< s, q >) = La_{\mathrm{l}}(s)$, and

$$\mathbf{P}(< s, q >, < s^{'}, q^{'} >) = \begin{cases} \mu(s^{'}) & \text{if } s^{'} \in Post(s), q^{'} = \Delta(q,s), \\ & \text{and } \mu = de(q,s) \in Post_{\mathrm{D}}(s) \\ 0 & \text{otherwise.} \end{cases}$$

If K is a finite PKS, then K_{S} is finite too [20]. If K_{S} has a terminal state s_n , a transition $\mathbf{P}(s_n, s_n) = 1$ is included, ensuring that K_{S} has no terminal state. Therefore, all executions of K_{S} are infinite. It is assumed that the state space of the model of the multi-threaded program and the shared memory used by the threads are finite.

A *combination* operator $\oplus$ is defined to combine two FPKSs in a single FPKS. Let $\mathrm{K}_i = (S_i, \mathbf{P}_i, \zeta_i, AP, La_i)$, $i = 1, 2$ be two FPKSs. The combination of K_1 and K_2 is defined as $\mathrm{K}_1 \oplus \mathrm{K}_2 = (S_1 â S_2, \mathbf{P}_1 â \mathbf{P}_2, \zeta_1 â \zeta_2, AP, La)$ where â stands for disjoint union and $La(s) = La_i(s)$ if $s \in S_i$.

IV. SPECIFYING WEAK PROBABILISTIC NON-INTERFERENCE

A multi-threaded program is secure when a *variation* of the values of the high variables does not influence the low-observable behavior of the program [6]. Thus, low-observable behavior of the program should be *indistinguishable* as high variables are varied. Variation of the values of high variables is represented by low-equivalence relation. Two states s_1 and s_2 are *low-equivalent*, denoted $s_1 =_L s_2$, if $La(s_1) = La(s_2)$. Smith [7] uses the notion of *weak probabilistic bisimulation* to represent the indistinguishability of low-observable behavior of the program.

Weak probabilistic bisimulation abstracts from steps that remain inside the equivalence classes, i.e., it does not care which state within the equivalence class the system is in [21]. Let $\mathrm{K} = (S, \mathbf{P}, \zeta, AP, La)$ be an FPKS and $R \subseteq S \times S$ be an equivalence relation. State s is *silent* with respect to R , if $\mathbf{P}(s, [s]_R) = 1$, i.e., s does not have a successor state outside $[s]_R$. Any state that is not silent with respect to R , may leave its equivalence class by a single transition with positive probability. Let S_{silent}^R denote the set of silent states with respect to R . For any state $s \notin S_{silent}^R$ and $C \in S / R$ with $C \neq [s]_R$

$$\mathbf{P}_c(s, C) = \frac{\mathbf{P}(s, C)}{1 - \mathbf{P}(s, [s]_R)}$$

denotes the conditional probability for non-silent state s to reach block C under the condition that being in s the system does not make a move inside $[s]_R$.

Definition 6 (Weak probabilistic bisimulation) [21], [22]: Let $\mathrm{K} = (S, \mathbf{P}, \zeta, AP, La)$ be an FPKS. A *weak probabilistic bisimulation* for K is an equivalence relation R on S such that for all $s_1 \; R \; s_2$:

- $s_1 =_L s_2$.
- If $\mathbf{P}(s_i, [s_i]_R) < 1$ for $i = 1, 2$ then for each equivalence class $C \in S / R$, $C \neq [s_1]_R = [s_2]_R$:
- $\mathbf{P}_c(s_1, C) = \mathbf{P}_c(s_2, C).$
- s_1 can reach a state outside $[s_1]_R$, iff s_2 can reach a state outside $[s_2]_R$.

States s_1 and s_2 are weak probabilistic bisimilar, denoted as $s_1 \approx_p s_2$, if there exists weak probabilistic bisimulation R for K such that $s_1 R s_2$.

Condition (1) asserts that states s_1 and s_2 are low-equivalent, and condition (2) ensures that their conditional probability to move to another equivalence class is the same. According to condition (3) for any equivalence class C , either for all $s \in C$: $s \in S_{silent}^R$ or for all $s \in C$ there is an execution fragment $\hat{\sigma} = s_0 s_1 \ldots s_n$ starting in $s = s_0$ with $n \geq 0$, $s_i \in C$ for $i = 1, \ldots, n-1$ and $s_n \notin C$.

Weak probabilistic bisimulation for pairs of executions is defined as follows:

Definition 7 (Weak probabilistic bisimilar executions): For infinite execution fragments $\sigma_i = s_{0,i}s_{1,i}s_{2,i}\dots$, $i = 1,2$ in K, σ_1 is weak probabilistic bisimilar to σ_2, denoted $\sigma_1 \approx_p \sigma_2$ if and only if there exists an infinite sequence of indices $0 = j_0 < j_1 < j_2 < \dots$ and $0 = k_0 < k_1 < k_2 < \dots$ with:

$s_{j,1} \approx_p s_{k,2}$ for all $j_{r-1} \leq j < j_r$ and $k_{r-1} \leq k < k_r$ with $r = 1,2,\dots$

In other words, two executions are weak probabilistic bisimilar, if they run through the same sequence of equivalence classes under $\approx_p$.

Smith [7] states that if a secure program is run starting from two low-equivalent states, then two executions must pass through the same sequence of equivalence classes. This is captured formally by the definition of weak probabilistic noninterference.

Definition 8 (Weak probabilistic noninterference): Given a finite-memory scheduler S, a multi-threaded program MT satisfies *weak probabilistic noninterference*, iff

$$\forall\, \sigma,\sigma' \in Execs(\mathrm{K}_{\mathsf{S}}).\ \sigma[0] =_L \sigma'[0] \ \Rightarrow\ \sigma \approx_p \sigma'$$

Where, K_{S} denotes an FPKS, modeling the executions of the program MT under the scheduler S, $=_L$ is low-equivalence relation between states, and $\approx_p$ is weak probabilistic bisimulation relation.

The intuition is that low-equivalent executions must visit the same sequence of equivalence classes of $\approx_p$, but some executions may run slowly than the others.

V. Verification

In this section an algorithm is developed to verify weak probabilistic noninterference. In what follows, a finite fully probabilistic Kripke structure $\mathrm{K}_{\mathsf{S}} = (S, \mathbf{P}, \zeta, AP, La)$ is fixed which models the executions of a multi-threaded program MT under a scheduler S. Let I denote the set of initial states of K_{S}, i.e., set of states s with $\zeta(s) > 0$.

A. The Algorithm

Weak probabilistic noninterference requires that all executions of the program with low-equivalent initial states must be weak probabilistic bisimilar. To verify this, the set of initial states I of K_{S} is partitioned into initial state blocks $\mathrm{IB}_0,\dots,\mathrm{IB}_m$. Each initial state block contains all low-equivalent initial states. Then, an arbitrary witness execution $w_i \in Execs(\mathrm{IB}_i)$ is chosen for each IB_i ($i \in \{0,1,\dots,m\}$) and FPKS K_{w_i} is created from w_i. K_{S} and all K_{w_i} are combined to form FPKS $\mathrm{K}' = (S', \mathbf{P}', \zeta', AP, La')$: $\mathrm{K}' = \mathrm{K}_{\mathsf{S}} \oplus \mathrm{K}_{w_0} \oplus \dots \oplus \mathrm{K}_{w_m}$. Now, K_{S} satisfies weak probabilistic noninterference if and only if $w_i[0]$ and all states of IB_i belong to the same equivalence class in the quotient space $\mathrm{K}'/\approx_p$, i.e., $\mathrm{IB}_i \subseteq [\,w_i[0]\,]_{\approx_p}$, where $[\,w_i[0]\,]_{\approx_p}$ denotes the equivalence class of $w_i[0]$ w.r.t. $\approx_p$.

The main steps of the verification algorithm are sketched in Algorithm 1. The algorithm takes a finite FPKS as input and returns secure if the FPKS satisfies weak probabilistic noninterference, and insecure if it does not. In the sequel, some steps of the algorithm are explained in more detail.

Taking a witness execution: As pointed out earlier, all executions of the input FPKS are infinite and hence form a cycle. To take a witness execution, a cycle detection algorithm based on depth-first search, called colored DFS, is used. The algorithm initially marks all states white. It then proceeds by moving to successor states and coloring them, and terminates when a colored state (i.e. a state that was encountered before) is visited. The sequence of states remains in the stack of the depth-first search form the witness execution.

Algorithm 1. Verification of Weak Probabilistic Non-interference

Input: finite FPKS K_{S}
Output: *secure*, if the program satisfies weak probabilistic noninterference;
insecure, otherwise;

Partition I into $\mathrm{IB}_0,\dots,\mathrm{IB}_m$;
Take a witness execution $w_i \in Execs(\mathrm{IB}_i)$ ($i \in \{0,1,...,m\}$);
Build FPKS K_{w_i} for each w_i;
Build FPKS $\mathrm{K}' = \mathrm{K}_{\mathsf{S}} \oplus \mathrm{K}_{w_0} \oplus \dots \oplus \mathrm{K}_{w_m}$;
Compute the quotient space $\mathrm{K}'/\approx_p$;
for each IB_i and the corresponding witness w_i do
  if $\mathrm{IB}_i \not\subseteq [\,w_i[0]\,]_{\approx_p}$ **then**
    return *insecure*;
  end if
end for
return *secure*;

Computing the quotient space w.r.t. $\approx_p$: Equivalence classes w.r.t. $\approx_p$ are computed using an approach similar to that of Baier and Hermanns [21]. The general idea of the computation algorithm is to use an iterative partition refinement technique. It starts from a trivial initial partition, where each block of the partition contains all low-equivalent states (condition (1) of the definition 6). It then successively refines the given partition by splitting any block of the partition into sub-blocks, eventually resulting in the set of weak probabilistic bisimulation equivalence classes. A general schema of the iterative refinement is depicted in Fig. 4.

The main idea for splitting each block B of the partition is to isolate non-silent states $s, s' \in B$ with equivalent conditional probability to some other block C, i.e. $\mathbf{P}_c(s,C) = \mathbf{P}_c(s',C)$, in order to ensure condition (2) of the definition 6. By condition (3) of the definition, each such non-silent isolated subblock $A \subseteq B$ has to be enriched with those silent states of B, which produce execution fragments that remain inside B and end up in A. Fig. 5 shows how B is refined into two subblocks.

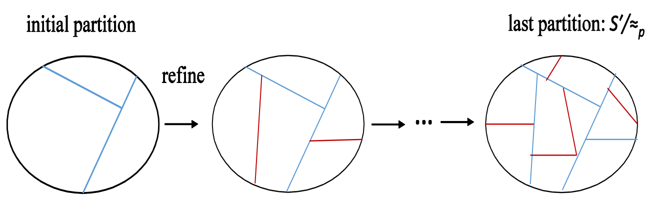

Fig. 4. Successive partition refinement to compute the quotient space.

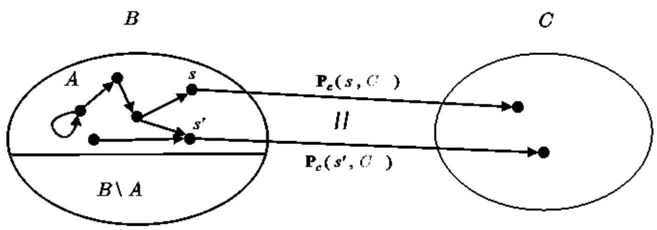

Fig. 5. Refinement of the block *B* into *A* and *B\A*.

B. Correctness of the Algorithm

Before diving into proving correctness of the proposed algorithm, a lemma is presented, which will be used in the correctness proof. This lemma asserts that $\approx_p$ can be lifted from states to executions and vice versa.

Lemma 1. Weak probabilistic bisimilar states have weak probabilistic bisimilar executions and vice versa:

$$s_1 \approx_p s_2 \text{ iff } \forall \sigma_1 \in Execs(s_1), \sigma_2 \in Execs(s_2).\ \sigma_1 \approx_p \sigma_2$$

Proof: "if": Let $\sigma_1 = s_{0,1}s_{1,1}s_{2,1}\ldots \in Execs(s_1)$ starting in $s_1 = s_{0,1}$ and $\sigma_2 = s_{0,2}s_{1,2}s_{2,2}\ldots \in Execs(s_2)$ starting in $s_2 = s_{0,2}$. By definition 7, if two executions are weak probabilistic bisimilar, then their initial states are weak probabilistic bisimilar too. Thus, $s_1 \approx_p s_2$.

"only if": Let $s_1 \approx_p s_2$ and $\sigma_1 = s_{0,1}s_{1,1}s_{2,1}\ldots \in Execs(s_1)$. Successively, a weak probabilistic bisimilar execution σ_2 starting in s_2 is defined by lifting the transitions from $s_{i,1}$ to $s_{i+1,1}$ with $s_{i,1} \not\approx_p s_{i+1,1}$ to finite execution fragments $s_{i,2}u_{i,1}\ldots u_{i,n_i}s_{i+1,2}$ (Fig. 6) such that:

$$s_{i,1} \approx_p s_{i,2},\ s_{i+1,1} \approx_p s_{i+1,2}, \text{ and } s_{i,2} \approx_p u_{i,1} \approx_p \ldots \approx_p u_{i,n_i}.$$

The proof is by induction on i. The base case $i = 0$ is straightforward and omitted. Assume $i \geq 0$ and that the execution fragment

$$\sigma_2 = s_{0,2}u_{0,1}\ldots u_{0,n_0}s_{1,2}u_{1,1}\ldots u_{1,n_1}s_{2,2}\ldots s_{i,2}$$

is already constructed. Distinguish two cases:

1) $s_{i,1} \not\approx_p s_{i+1,1}$. Since $s_{i,1} \approx_p s_{i,2}$ and $\mathbf{P}(s_{i,1}, s_{i+1,1}) > 0$, there exists a finite execution fragment $\hat{\sigma}_2' = s_{i,2}u_{i,1}\ldots u_{i,n_i}s_{i+1,2}$ such that: $s_{i+1,1} \approx_p s_{i+1,2}$ and $s_{i,2} \approx_p u_{i,1} \approx_p \ldots \approx_p u_{i,n_i}$. Concatenating the execution fragment $\hat{\sigma}_2$ with the execution fragment $\hat{\sigma}_2'$ yields an execution fragment that fulfills the desired conditions.

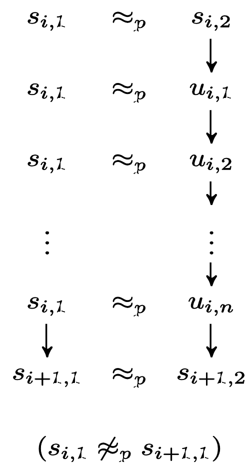

Fig. 6. Construction of a weak probabilistic bisimilar execution.

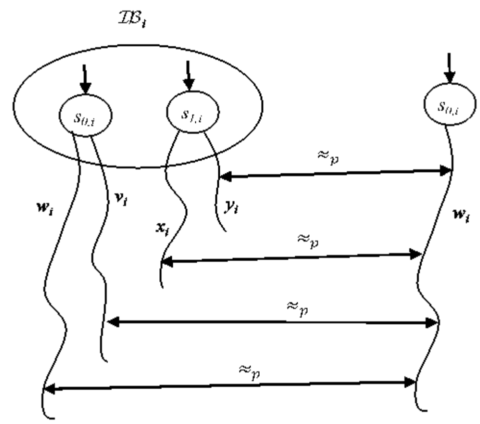

Fig. 7. Relation between the witness execution w_i and other executions of IB_i.

2) $s_{i,1} \approx_p s_{i+1,1}$. Distinguish between $s_{i,1}$ can reach outside $[s_{i,1}]_{\approx_p}$ and cannot reach outside $[s_{i,1}]_{\approx_p}$:

a) $s_{i,1}$ can reach outside $[s_{i,1}]_{\approx_p}$, i.e., there exists an index $j > i+1$ with $s_{i,1} \not\approx_p s_{j,1}$. Without loss of generality, assume that j is minimal, i.e., $s_{i,1} \approx_p s_{i+1,1} \approx_p \ldots \approx_p s_{j-1,1}$ $s_{j-1,1} \not\approx_p s_{j,1}$. As $s_{i,2} \approx_p s_{j-1,1}$ and $\mathbf{P}(s_{j-1,1}, s_{j,1}) > 0$, there exists a finite execution fragment $\hat{\sigma}_2' = s_{i,2}u_{i,1}\ldots u_{i,n_i}s_{i+1,2}$ such that $s_{j,1} \approx_p s_{i+1,2}$ and $s_{i,2} \approx_p u_{i,1} \approx_p \ldots \approx_p u_{i,n_i}$. Concatenation of the execution fragment $\hat{\sigma}_2$ with the execution fragment $\hat{\sigma}_2'$ yields an execution fragment that fulfills the desired conditions.

b) $s_{i,1}$ cannot reach outside $[s_{i,1}]_{\approx_p}$, i.e., $s_{i,1} \approx_p s_{j,1}$ for all $j \geq i$. As $s_{i,1} \approx_p s_{i,2}$, and $s_{i,1}$ cannot reach outside $[s_{i,1}]_{\approx_p}$, $s_{i,2}$ cannot reach outside $[s_{i,2}]_{\approx_p}$ (see condition (3) of definition 6), i.e., there is an execution $s_{i,2}s_{i+1,2}s_{i+2,2}\ldots$ with $s_{i,2} \approx_p s_{i+1,2} \approx_p s_{i+2,2} \approx_p \ldots$. Concatenating the execution fragment $\hat{\sigma}_2$ with the execution fragment $s_{i,2}s_{i+1,2}s_{i+2,2}\dots$ yields an execution that fulfills the desired conditions. Consequently, the resulting execution σ_2 is weak probabilistic bisimilar to σ_1.

The following theorem proves correctness of the Algorithm 1.

Theorem 1. Algorithm 1 returns secure if and only if the input FPKS K_{S} satisfies weak probabilistic non-interference.

Proof: The algorithm starts by partitioning I into low-equivalent sets of states $\mathrm{IB}_0,\dots,\mathrm{IB}_m$. Then, a witness execution $w_i \in Execs(\mathrm{IB}_i)$ is chosen and Kripke structures $\mathrm{K}_{w_0},\dots,\mathrm{K}_{w_m}$, and K' are created. Now, the problem of K_{S} satisfying weak probabilistic noninterference is reduced to checking weak probabilistic bisimilarity between w_i and each $\sigma \in Execs(\mathrm{IB}_i)$. For example, in Fig. 7, the relation $\approx_p$ should be established between the witness execution w_i and all executions in $Execs(\mathrm{IB}_i)$, i.e., w_i, v_i, x_i, y_i.

According to lemma 1, w_i and σ are weak probabilistic bisimilar if and only if their initial states, i.e., $w_i[0]$ and $\sigma[0]$ are weak probabilistic bisimilar:

$$w_i \approx_p \sigma \text{ iff } w_i[0] \approx_p \sigma[0]$$

Given that $\approx_p$ was defined as an equivalence relation, $w_i[0] \approx_p \sigma[0]$ if and only if $w_i[0]$ and $\sigma[0]$ belong to the same equivalence class in the quotient space $\mathrm{K}'/\approx_p$. Thus, each $\sigma[0]$, i.e., all states of IB_i, should belong to $[\,w_i[0]\,]_{\approx_p}$. In other words, for each initial state block IB_i and the corresponding witness execution w_i, it should be $\mathrm{IB}_i \subseteq [\,w_i[0]\,]_{\approx_p}$.

C. Complexity of the Algorithm

For computing the initial state blocks, *HashMap* class of Java was used. The worst case complexity of inserting a key-value pair to the hash map is $O(|AP|)$. Hence, the time complexity of computing the initial state blocks is $O(|\mathrm{I}|.|AP|)$.

Let t be the number of transitions of K_{S}. A witness execution can be extracted in time $O(t+|S|)$. Thus, the time complexity of extracting all witness executions is $O(|\mathrm{I}|.(t+|S|))$.

The quotient space $\mathrm{K}'/\approx_p$ can be constructed in time $O(|S'|^3)$ [21]. Assuming $|S| \le t$ and considering the fact that $\frac{|S'|}{2} \le |S|$, verification of weak probabilistic noninterference can be implemented in time $O(|S|^3 + |\mathrm{I}|.(t+|AP|))$.

D. Case Study

The algorithm proposed in this paper has been implemented as part of *SCT* (Security Certifying Tool), which has been developed in JAVA to verify secure information flow for multi-threaded programs. SCT gets a probabilistic Kripke structure as model of the program and checks whether the program satisfies weak probabilistic noninterference. To our knowledge, no other algorithmic verification technique for weak probabilistic noninterference has been published, so it is not possible to compare the implementation to other algorithms.

As a case study, consider the problem of *dining cryptographers*. The problem is borrowed from [11] to show how an attacker can deduce secret information through probabilistic leaks. David Chaum first proposed this problem in 1988 as an example of anonymity and identity hiding [23]. In this problem, three cryptographers are sitting at a round table to have dinner at their favorite restaurant. The waiter informs them that the meal has been arranged to be paid by one of the cryptographers or their master. The cryptographers respect each other's right to stay anonymous, but would like to know whether the master is paying or not. So, they decide to take part in the following two-stage protocol:

- Stage 1: Each cryptographer tosses an unbiased coin and only informs the cryptographer on the right of the outcome. The situation is illustrated in Fig. 8. In this figure, c1, c2, and c3 are identities of cryptographer 1, cryptographer 2, and cryptographer 3 respectively.
- Stage 2: Each cryptographer publicly announces whether the two coins that she can see are the same ('agree') or different ('disagree'). However, if she actually paid for the dinner, then she lies, i.e., she announces 'disagree' when the coins are the same, and 'agree' when they are different.

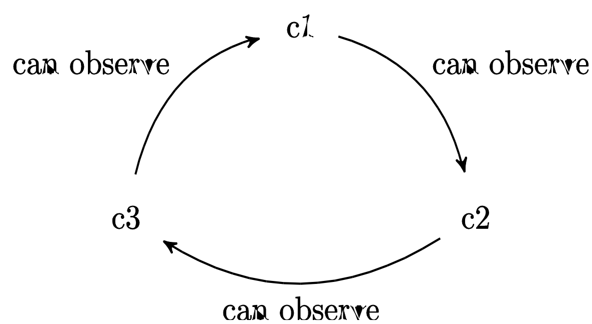

Fig. 8. Dining cryptographers. c1 can observe c2's coin, and c2 can observe c3's coin.

An even number of 'agree's implies that none of the cryptographers paid (the master paid), while an odd number implies that one of the cryptographers paid. David Chaum names this protocol as *Dining Cryptographers network* or DC-net. DC-net is secure, since it does not leak the identity of the paying cryptographer (in case one of the cryptographers made arrangement to pay for the meal). Following Ngo [11], to make this protocol leak information, a slight change is done: coins are *biased*, i.e., with probability 0.6 it comes up heads, and with probability 0.4 it comes up tails.

To model the case study, *PRISM* has been used. PRISM is a tool for formal modeling and analysis of probabilistic systems [24]. PRISM describes models using the PRISM language, a simple, state-based language with a guarded command notation. The program is implemented in PRISM and its model is built. Then, export the explicit-state model, containing the set of reachable states and their labels, along with the transition matrix. Then, the model is given to SCT to compute the quotient space and check the security property. SCT was run on a PC with a Core i3 2.53 GHz CPU and 6 GB RAM.

Without lack of generality, suppose one of the cryptographers has made arrangement for the meal, and the other one is the attacker, i.e., the one who tries to find out the payer's identity. The FPKS K_S of the model built by PRISM has 285 states and 582 transitions. K_S has just 3 initial states. All initial states have the same label value of $\{0\}$ (label values are explained in the next paragraph). Thus, a witness execution w_0 is extracted from K_S and $K' = K_S \oplus K_{w_0}$ is built. K' has 292 states and 589 transitions. The quotient space $K'/\approx_p$ is computed in 1.672 seconds and has 13 equivalence classes. As expected, the initial states and $w_i[0]$ do not belong to same equivalence class and hence SCT correctly recognizes the model as insecure.

To see how an attacker can infer the identity of the payer, consider an example scenario where cryptographer 2 is the attacker and aims to find out which one of the cryptographers 1 or 3 is the payer. Suppose cryptographer 2 and cryptographer 3 both toss tail. Cryptographer 2 can observe the coin of cryptographer 3, and thus announces 'agree'. Assume cryptographer 2 observes that cryptographer 1 announces 'agree' and cryptographer 3 announces 'disagree' for the values of the coins. Two situations corresponding to this case are shown in Fig. 9 and executions of these situations are outlined in Fig. 10. In Fig. 10, each state is represented as 10-tuples listing the current values of the variables (*pay*, *agree1*, *agree2*, *agree3*, *coin1*, *s1*, *coin2*, *s2*, *coin3*, *s3*) and labeled with the current value of parity: 0 for even number of 'agree's, and 1 for odd number of 'agree's. The variable *pay* contains the number of the cryptographer who is actually the payer. Variables *agree1*, *agree2*, and *agree3* contain the announcements of cryptographer 1, 2, and 3, respectively: 0 for 'disagree', and 1 for 'agree'. Variables *coin1*, *coin2*, and *coin3* contain the coin values for cryptographer 1, 2, and 3, respectively: 1 for head, and 2 for tail. Finally, variables *s1*, *s2*, and *s3* contain the status values for the three cryptographers: 0 for 'not done', and 1 for 'done'.

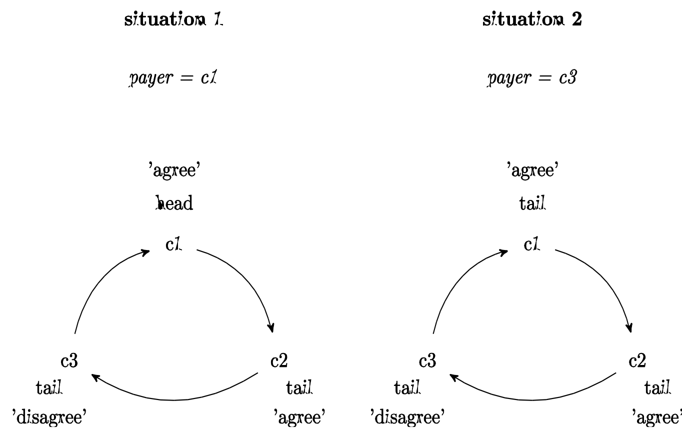

Fig. 9. Two situations corresponding to the case where c2 and c3 both toss tail.

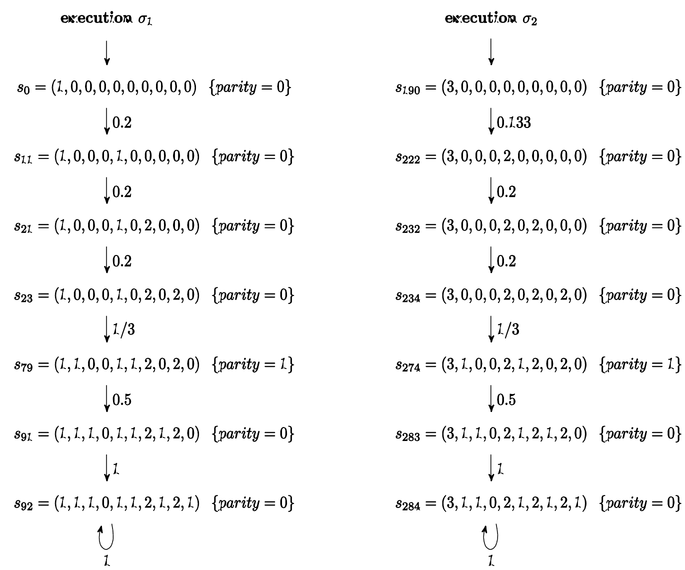

Fig. 10. Two executions corresponding to the situations 1 and 2.

Execution σ_1 occurs when cryptographer 1 is the payer and tosses head. Therefore, cryptographer 1 announces 'agree' and cryptographer 3 announces 'disagree'. Execution σ_2 occurs when cryptographer 3 is the payer and tosses tail. Thus, cryptographer 3 announces 'disagree' and cryptographer 1 announces 'agree'. As seen in Fig. 10, the probability of σ_1 (i.e. cryptographer 1 tossing head) is more than the probability of σ_2 (i.e. cryptographer 1 tossing tail) and hence the attacker can deduce that cryptographer 1 is more likely to be the payer. This is a probabilistic leak.

VI. Related Work

In the following, some related approaches from the literature are discussed and the proposed approach is compared with them.

Barthe et al. [10] propose the idea of self-composition for logical characterization of information flow properties. Self-composition reduces the problem of verifying information flow property for a program *P* to a safety property for a program derived from *P*, by composing *P* with a renaming of itself. Then, standard model checking and algorithmic verification techniques can be used to verify secure information flow. Terauchi and Aiken [14] introduce 2-safety properties, which can be refuted by observing two executions. They show that termination insensitive secure information flow problem is a 2-safety problem. They further generalize the idea of self-composition and show that it can be used to verify 2-safety properties. Huisman et al. [15] use the idea of self-composition to characterize secure information flow in CTL* and modal μ-calculus temporal logics. They specify secure information flow using observational determinism, an information flow property proposed by Zdancevic and Myers [25] for concurrent programs. Van der Meyden and Zhang [16] employ a self-composition-like method to reason about noninterference properties and develop algorithmic verification techniques for these properties. They characterize the computational complexity of the developed verification techniques and discuss some possible heuristics for optimizing the verification. Verification methods that use the idea of self-composition suffer from the state-space explosion problem, i.e., space needed to store the states and transitions of the program exceed the available memory. This occurs because in self-composition a program model is composed with a copy of itself. In the proposed algorithm, the program model is composed with only a small part of the model (witness execution). Furthermore, security analysis is done on the abstract model (quotient space), not on the concrete model.

Ngo et al. [26] propose scheduler-specific probabilistic observational determinism as a property to specify secure information flow for probabilistic multi-threaded programs. They define the property based on two conditions. First condition requires that all traces of each public variable starting in the same initial state are stuttering equivalent. A trace of an execution is a mapping of states of the execution to the corresponding state labels. Two traces are stuttering equivalent if they become the same after removing repeating adjacent labels. Second condition requires that for all traces of an initial state s_i, there exists a trace of an initial state $s_i^{'}$ low-equivalent to s_i, that is stuttering equivalent to each one of the traces of s_i and the probabilities of the traces are the same. Condition 2 of this property is closest in semantics to our definition of weak probabilistic noninterference. Of course, weak probabilistic noninterference requires weak probabilistic bisimulation between executions, which is different from stuttering equivalence. To verify condition 2 of their property, Ngo et al build two FPKSs for each pair of initial states s_i and $s_i^{'}$. Then, they transform the FPKSs to stuttering-free ones and check equivalence of the probabilistic languages arising from executions of the two FPKSs using an off-the-shelf algorithm. The time complexity of the algorithm is $O(n^3)$ for each pair of initial states s_i and $s_i^{'}$, where n is the number of states of each FPKS. The deficiency of this verification algorithm is that it builds two copies of the program for each pair of initial states. It is clear that if the input program has enormous state space, then the algorithm would suffer from the state explosion problem.

A trending field in security verification is proof-based verification, in which mathematical logic is used to describe the program, specify the property of interest, and *prove* satisfiability of the property. Hoare logic [27] is one of the most widely-used logics for proof-based verification of software. Variants of Hoare logic have been proposed for verifying relational, and in particular, k-safety properties [28-30]. An advantage of these techniques is that they avoid the state-space explosion problem, because they do not check the whole state space of the program. Consequently, they are suitable for verifying programs with huge, and even infinite, state space. A disadvantage with these techniques is that they are semi-automatic. Although many of the proof steps are done mechanically, some steps need expert user intervention. This contrasts with algorithmic verification, which is fully automatic.

VII. Conclusions and Future Work

In this paper, the problem of verifying weak probabilistic noninterference was discussed. Weak probabilistic noninterference is a notion of confidentiality for multi-threaded programs. The behavior of multi-threaded programs running under the control of a scheduler was modeled by probabilistic Kripke structures. Weak probabilistic noninterference was formalized in terms of executions of the probabilistic Kripke structure. Then, a verification algorithm was proposed to check the property.

As future work, we plan to use the proposed algorithm to verify other information flow properties. We believe the applicability of the algorithm can be extended and it can be used to verify many security properties, such as strong security [6] and probabilistic noninterference [6]. In an earlier paper [31], we used a similar algorithm to verify observational determinism.

A disadvantage of the proposed verification algorithm is that it works on explicit model of the program, which may be too huge for real-world programs. This harms scalability of the approach. To solve this problem, one can change the algorithm in such a way that it works on abstract models of the program, such as binary decision diagrams.

We also aim to modify the algorithm to support compositional verification, thereby reducing conceptual complexity and making the analysis scale.

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Balanced Active and Reactive Control Applied to a Grid Connected Five Level Inverter

Chabakata MAHAMAT
University of Tunis El Manar,
Faculty of Sciences of Tunis &
ENS of Paris-Saclay
Laboratories: SATIE & LAPER

Mickaël PETIT
National Conservatory of Arts and Crafts (Cnam) of Paris, CNRS,
Laboratory: SATIE
Cachan, France

François COSTA
Université Paris Est Créteil
ESPE of Créteil, CNRS,
Laboratory: SATIE
Cachan, France

Rym MAROUANI
University of Tunis El Manar
Faculty of Sciences of Tunis, Laboratory: LAPER
Tunis, Tunisia

Abdelkader MAMI
University of Tunis El Manar
Faculty of Sciences of Tunis, Laboratory: LAPER
Tunis, Tunisia

***Abstract*—This paper presents a balanced active and reactive power control, using a Phase Locked Loop for synchronization, and applied to a grid connected Five Level Inverter. The energy source of the system can be a photovoltaic generator or a wind turbine. We size the passive elements of the system and explain the value of the system architecture using a Five Level Inverter when compared to a classical grid connected system. We also compare the balanced active and reactive power control to an unbalanced active and reactive power control. The simulation results obtained by using Matlab Simulink and Simpowersystems are presented and discussed in this paper.**

***Keywords*—Balanced control; grid connected system; multilevel inverter**

I. INTRODUCTION

Maximizing the power transfer from the energy source to the electrical grid and optimizing the system dynamics both depend on the used static converter technology and its control algorithms [1]. In grid-connected system, we must use a LCL filter to connect the inverter to the utility grid in order to obtain a good attenuation of high frequency harmonics generated by the inverter [1], [2], [7]. This is the case of [1]-[3], [15], [17] and [18]. However, using a LCL-filter requires a sophisticated control, due to the increase in filter order. Insofar as it is no longer possible to control the system using traditional controllers (PI: Proportional Integral), we must use other types of control such as cascade controllers, sliding mode control, fuzzy logic control as in [11], [12] and [16] .

To solve this problem, we propose an architecture of grid-connected system using a Five-Level Inverter (FLI) with an interleaved L-filter and controlled by a balancing PQ-control. The use of this innovative structure using a FLI in this domain should allow a decrease in filter volume and a gain in system reliability, and in energy quality.

So the objectives of this work are to analyze the grid-connected system using an FLI with an interleaved L-filter and to show the value of this architecture compared to the classical grid-connected system. We are particularly interested in balancing control and sizing of this system, in a context of use in Africa where the cost, reliability and energy quality issues of the system should be taken into account. The considered grid is a low voltage grid (230 V) with a frequency equal to fifty hertz (50 Hz) but likely to vary, in which a maximum power of five point two kilowatts (5.2 kW) is injected. Those are the standards of the national electricity company of Chad (SNE: Société Nationale d'Electricité du Tchad).

This work is organized as follows: Section II describes the system under study, Section III presents the FLI principle, Section IV presents the sizing of passive elements, and Section V details the system's modeling and control. Finally, the simulation results and discussion are provided in Section VI.

II. DESCRIPTION OF THE SYSTEM

Fig. 1 shows the proposed architecture of the grid connected system and its control.

This system is composed of two parts: a continuous part (DC) and an alternative part (AC). The DC part is the energy source which can be a photovoltaic generator or a wind turbine. The AC part is composed by the FLI, the utility grid and is controlled by a balanced active and reactive power control (PQ - control). A Phase-Locked Loop (PLL) is used to synchronize the system with the grid. The balanced PQ - control is composed of two control loops : an external control loop to control the output current in the Park frame and an internal control loop for local balancing of the cell currents which is done in the abc frame.

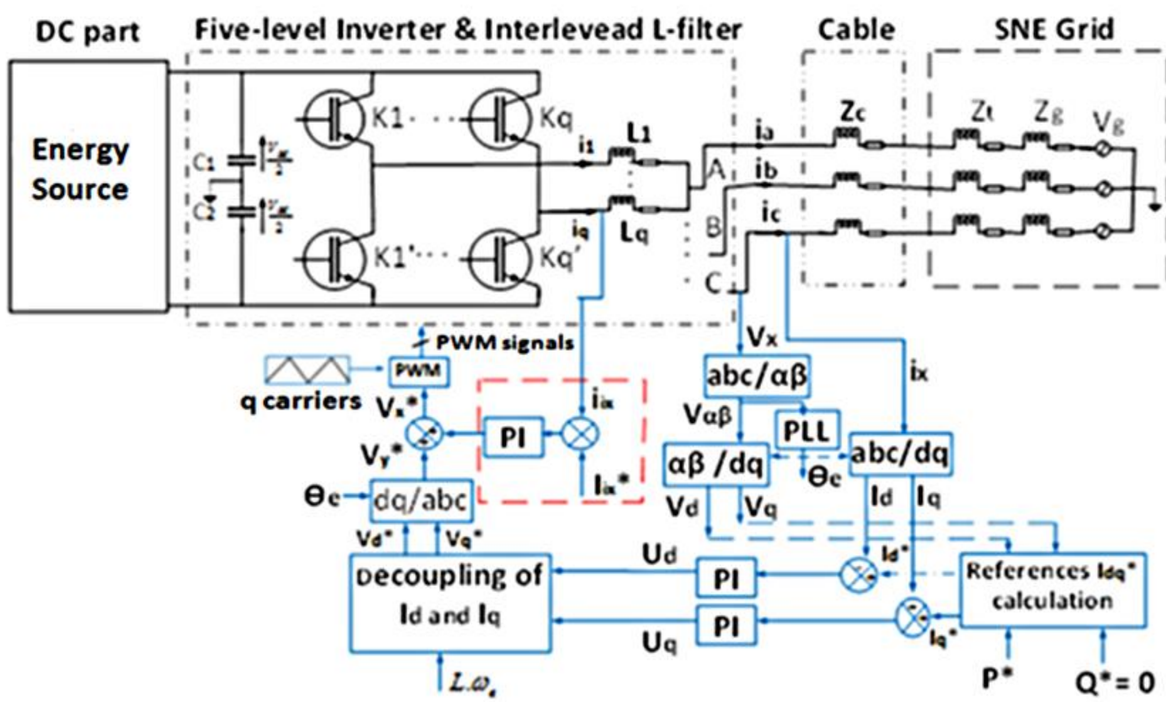

Fig. 1. Grid connected system and its control.

III. Principle of the Five-Level Inverter (FLI)

The simplified diagram of the three-phase FLI is shown in Fig. 2, where $x = a, b, c$ is the phase name of the FLI. It is a parallel structure composed of four interleaved cells.

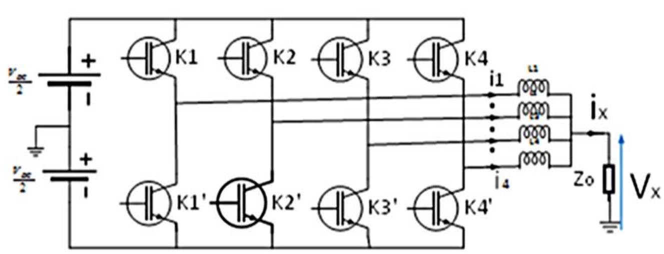

Fig. 2. Simplified diagram of the $\boldsymbol{FLI}$ with L-filter.

As in a classical inverter, the two switches of the same inverter arm are controlled complementarily to avoid short circuits. $K_{ix} = \overline{K'_{ix}}$; Where $i = \{1,2,3,4\}$ is the cell number. The q different switching cells are shifted by $\frac{T_{sw}}{q}$ and controlled with the same duty cycle [4], [5]. Where $q = 4$ and T_{sw} is the switching period. The three phases of the inverter (a, b, c) are also shifted by $\frac{2\pi}{3}$.

To simplify, the study of the three-phase inverter can be reduced to a single phase. Fig. 3 shows the output voltage waveforms of the FLI and classical inverter (two-level inverter) for one phase when a RL load is connected (For specifications of the FLI + load, cf. Table 2).

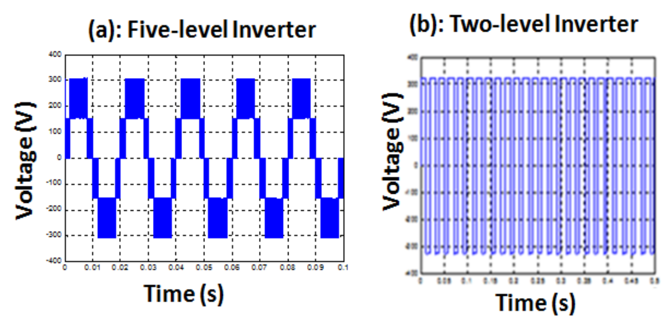

Fig. 3. Waveforms of the voltage vs. time.

Contrary to the waveform of the classical two-level inverter (Fig. 3(b)), the waveform of the FLI is more sinusoidal (Fig. 3(a)). Indeed, this waveform is less rich in harmonics. Moreover, these harmonics are at the apparent frequency which is equal to q times the switching frequency, so they are easy to filter. We can therefore use small caliber passive elements to make the filter.

Furthermore, we can see in Fig. 3(a) that the waveform of the voltage has five voltage levels (two alternating positive + two alternating negative + zero level); hence, the name of the Five Level Inverter (FLI).

IV. Modeling and Sizing of the System

A. Grid modeling

1) Medium voltage model of the grid

The considered medium voltage line (15 kV) of the SNE grid has a distance $d = 9.3$ km and a section $S = 185\ \text{mm}^2$

[8]. So, the resistance of the medium voltage line (R_{1g}) is calculated in (1).

$$R_{1g} = \frac{\rho \cdot d}{S} \quad (1)$$

Where ρ is the aluminum resistivity. In the case of Chad which is a hot country with an ambient temperature substantially equal to $T_{amb} = 40\ °C$ [8], we can consider a maximum temperature equal to $T = 75\ °C$. In addition, this temperature corresponds to the temperature indicated in the datasheet of the considered transformer [9]. In this case, $\rho = 3.5929 \cdot 10^{-8}\ \Omega \cdot m$ (if $T = T_0 = 20\ °C$, $\rho = \rho_0 = 2.941 \cdot 10^{-8}\ \Omega \cdot m$) and $R_{1g} = 1.8\ \Omega$.

The linear reactance is equal to $X_l = 0.4\ \Omega/km$ [8]. So the grid medium voltage line inductance is given in (2).

$$L_{1g} = \frac{X_l \cdot d}{\omega} \quad (2)$$

Where ω is the grid pulsation ($\omega = 2\pi f$). For $= 50$ Hz , we obtain $L_{1g} = 11.8$ mH.

2) Low voltage model of the grid

To switch from the medium voltage model to the low voltage model, we use the transformer model seen Fig. 4.

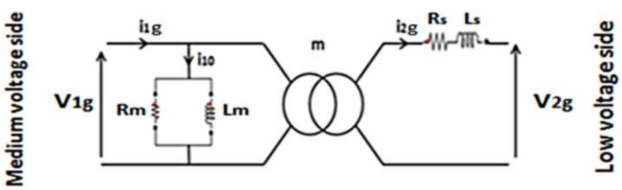

Fig. 4. Simplified transformer model.

By neglecting the losses in the transformer, we can write the power conservation relation in (3).

$$V_{1g} \cdot i_{1g} = V_{2g} \cdot i_{2g} \quad (3)$$

With $V_{1g} = Z_{1g} \cdot i_{1g}$, $V_{2g} = Z_{2g} \cdot i_{2g}$ and using (3), we can write (4).

$$Z_{2g} = Z_{1g} \cdot \left(\frac{i_{1g}}{i_{2g}}\right)^2 \quad (4)$$

On the other hand,

$$m = \frac{V_{2g}}{V_{1g}} = \frac{i_{1g}}{i_{2g}} \quad (5)$$

So $\quad i_{1g} = m \cdot i_{2g} \quad$ (6)

Using (6), (4) becomes (7).

$$Z_{2g} = m^2 \cdot Z_{1g} \quad (7)$$

Therefore,

$$\begin{cases} R_{2g} = m^2 \cdot R_{1g} \\ L_{2g} = m^2 \cdot L_{1g} \end{cases} \quad (8)$$

Where,

V_{1g} and V_{2g} are the medium and low grid line-to-phase voltages respectively;

i_{1g} and i_{2g} are the medium voltage side and low voltage side grid currents;

Z_{1g} and Z_{2g} are the medium voltage side and low voltage side grid impedances ;

R_{1g} and R_{2g} are the medium voltage side and low voltage side grid resistances;

L_{1g} and L_{2g} are the medium voltage side and low voltage side grid inductances;

And m is the voltage ratio.

Note: R_{1g}, L_{1g} , R_{2g} and L_{2g} are not represented in Fig. 4. Only the internal elements (R_m, L_m, R_s, L_s) of the transformer are presented in Fig. 4. The line capacitor is neglected here, so the grid impedance is only composed of its resistance and inductance.

To simplify, we set: $R_{2g} = R_g$, $L_{2g} = L_g$ and $Z_{2g} = Z_g$.

The transformer line-to-phase voltages are: $U_1 = 15$ kV and $U_2 = 400$ V [8].

So, $V_{1g} = \frac{U_1}{\sqrt{3}} = 8.66$ kV , $V_{2g} = \frac{U_2}{\sqrt{3}} = 230$ V and $m = 0.0267$.

Thus, using (8), we obtain the grid impedance parameters of the low voltage model: $R_g = 1.3\ m\Omega$ and $L_g = 8.4\ \mu H$.

So the module of the grid impedance is given in (9).

$$Z_g = \sqrt{{R_g}^2 + (L_g \cdot \omega)^2} \quad (9)$$

Where $\omega = 2\pi f$ is the grid pulsation (f is the grid frequency).

For $= 50$ Hz , we obtain $Z_g \approx R_g = 3\ m\Omega$.

B. Impedance of the transformer

The model of the considered transformer is shown in Fig. 4. Some characteristics of this transformer are given in Table 1 [9].

TABLE I. CHARACTERISTICS OF THE TRANSFORMER

Symbol	Parameter	Value	Unit
S_n	Rated power	250	kVA
U_1	Primary phase-to-phase rated voltage	15	kV
V_1	Primary line-to-phase rated voltage	8.66	kV
U_{20}	Phase-to-phase open circuit secondary voltage	410	V
V_{20}	Line-to-phase open circuit secondary voltage	237	V
u_{cc}	Short circuit voltage	4	%
I_{10}	Open circuit current	0.5	%
P_j	Losses due to load at 75 ° C	3250	W
P_f	Open circuit losses	300	W

1) Open circuit test and magnetic elements calculation

The magnetic elements R_m and L_m of the transformer are calculated by the open circuit test as indicated in (10) and (12).

$$R_m = \frac{V_1{}^2}{P_{10}} \quad 10)$$

$$X_m = \frac{V_1{}^2}{Q_{10}} \quad (11)$$

$$L_m = \frac{X_m}{\omega} \quad (12)$$

Where: R_m is the magnetic resistance; X_m is the magnetic reactance; P_{10} is the active iron losses; Q_{10} is the reactive iron losses and L_m is the magnetic inductance.

The active and reactive iron losses are calculated as follows:

$$S_{10} = V_1 . I_{10} \quad (13)$$

$$I_{10} = 0.5\% \cdot I_{1n} \quad (14)$$

$$I_{1n} = \frac{S_n}{3 \cdot V_1} \quad (15)$$

On the other hand, characteristics of the Table 1 are given in the case of a three-phase system. For the active iron losses of one phase P_{10}, we can consider the open circuit losses (P_f) divided by three as shown in (16).

$$P_{10} = \frac{P_f}{3} \quad (16)$$

So the reactive iron losses are calculated in (17).

$$Q_{10} = \sqrt{S_{10}{}^2 - P_{10}{}^2} \quad (17)$$

By injecting (16) in (10), (17) in (11) and using Table 1, we obtain: $R_m = 750\ \text{k}\Omega$ and $X_m = 1.854 \cdot 10^5\ \Omega$. Finally, using (12) we obtain $L_m = 590.208$ H.

2) Short circuit test and serial elements calculation

The serial resistance R_s and inductance L_s of the transformer are calculated by the short circuit test. The formula of the serial resistance is given in (18).

$$R_s = \frac{P_j}{3 \cdot I_{2n}{}^2} \quad (18)$$

Where I_{2n} is the rated secondary current.

$$I_{2n} = \frac{S_n}{3 \cdot V_{20}} \quad (19)$$

By (18) and (19) and using table I, we obtain $R_s = 8.8\ \text{m}\Omega$.

The mainly parameters which allow to calculate the serial inductance of the transformer L_s are the following:

$$V_{2cc} = \frac{u_{cc}}{100} \cdot m . V_1 \quad (20)$$

$$S_{cc} = V_{2cc} \cdot I_{2n} \quad (21)$$

For the active short circuit losses of one phase P_{cc}, we can consider the losses due to load P_j divided by three as shown in (22). Because the parameters of Table 1 are given in the case of a three-phase system.

$$P_{cc} = \frac{P_j}{3} \quad (22)$$

$$Q_{cc} = \sqrt{S_{cc}{}^2 - P_{cc}{}^2} \quad (23)$$

$$X_s = \frac{Q_{cc}}{I_{2n}{}^2} \quad (24)$$

$$L_s = \frac{X_S}{\omega} \quad (25)$$

Where: V_{2cc} is the secondary short circuit voltage; S_{cc} is the apparent short circuit losses; P_{cc} is the active short circuit losses; Q_{cc} is the reactive short circuit losses and X_s is the reactance of the transformer.

By considering the above parameters, we obtain $L_s = 81\ \mu\text{H}$.

Note: We can neglect the magnetic resistance R_m and inductance L_m of the transformer because they have very high values and are connected in parallel (cf. Fig. 4). Thus the internal resistance and inductance of the transformer are equal to the serial resistance and the inductance: $L_t = L_s$ and $R_t = R_s$. So the module of the transformer's impedance is given in (26).

$$Z_t = \sqrt{R_t{}^2 + (L_t \cdot \omega)^2} \quad (26)$$

For $= 50$ Hz , we obtain $Z_t = 27\ \text{m}\Omega$.

C. Impedance of the Cable

We consider that the distance between the common connection point of the grid and our installation is equal to $d_1 = 200$ m. For this short distance, the capacitor of the cable can be neglected and the model of the cable is only composed of a resistance and an inductance. In addition, a three-phase aluminum cable with a section equal to $S = 6\ \text{mm}^2$ is selected.

The formula of the cable resistance R_c is indicated in (27).

$$R_c = \rho \frac{d_1}{S} \quad (27)$$

Where ρ is the aluminum resistivity ($\rho = 3.5929 \cdot 10^{-8}\ \Omega \cdot \text{m}$ at $T = 75$ °C). So we obtain $R_c = 1.2\ \Omega$.

And the formula of the cable inductance L_c is given in (28).

$$L_c = \frac{X_c}{\omega} \quad (28)$$

Where X_c is the reactance of the cable.

$$X_c = X_l \cdot d_1 \quad (29)$$

Where X_l is the linear reactance of the cable ($X_l = 0.08\ \text{m}\Omega/\text{m}$) [8]. By injecting (29) in (28), we obtain $L_c = 51\ \mu\text{H}$. So the impedance of the cable is given in (30).

$$Z_c = \sqrt{R_c{}^2 + (L_c \cdot \omega)^2} \quad (30)$$

For $f = 50$ Hz, we obtain $Z_c \approx R_c = 1.2\ \Omega$.

D. The Interleaved Inductance (Filter Inductance)

The four inductances of the interleaved L - filter are identical. The value of these inductances is selected to obtain a current harmonic distortion THD of less than five percent ($THD < 5\,\%$) in order to respect the connection standard $IEEE1547$ [10]. In addition, nowadays there are photovoltaic inverters on the market with a THD lower than or equal to 3 %. Therefore, we are focusing on those existing solutions. Fig. 5 shows the THD of current versus (vs) inductance.

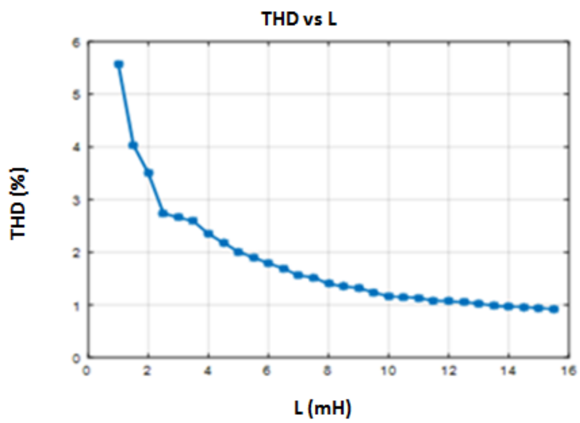

Fig. 5. Selection of the interleaved filter inductance.

We can see in Fig. 5 that for $L = 2.5$ mH, $THD < 3\,\%$, so this inductance value will be selected. Therefore, we use four identical inductances to make the interleaved L - filter ($L_1 = L_2 = L_3 = L_4 = L_f = 2.5$ mH).

The passive elements of our system are summarized in Table 2. To compare filter volumes, the same inductances values are considered both in the classical inverter and in the FLI.

TABLE II. SPECIFICATIONS OF THE PASSIVE ELEMENTS

Symbol	Parameter	Value		Unit
		classical inverter	*FLI (q = 4)*	
P_{max}	Maximum power	5.2	5.2	kW
V_{DC}	DC bus voltage	700	700	V
V_g	Grid RMS voltage	230	230	V
L_g	Grid side inductance	8.4	8.4	μH
L_t	Transformer inductance	81	81	μH
L_c	Cable inductance	51	51	μH
L_f	Filter inductance	2.5	2.5	mH
R_f	Binding filter resistance	0.5	0.5	Ω
R_c	Cable resistance	1.3	1.3	Ω
R_t	Transformer resistance	8.8	8.8	mΩ
R_g	Grid side resistance	1.3	1.3	mΩ
f_{sw}	Switching frequency	20	20	kHz
f	Grid frequency	50	50	Hz
I_{o_max}	Maximum output current	11.28	10.67	A
I_{L_max}	Maximum cell current	11.28	3	A
ΔI_{cell}	Cell current ripple	0.62	0.3	A
ΔI_{o_max}	Output current ripple	0.62	0.01	A

Note: The maximum amplitude of output current shown in this table takes into account the current ripple. Its fundamental value is equal to : $I_{max} = 10.66$ A.

Using Table 2, we calculate and compare the volumes of passive elements as follows [7], [13]:

❖ In general:

- Energy:

$$W = \frac{1}{2} L I_{L\_max}{}^2 \tag{31}$$

- Volume:

$$V_{ol} \propto W^{3/4} \tag{32}$$

$$Vol \propto \frac{1}{2} L^{3/4} I_{L\_max}{}^{3/2} \tag{33}$$

So,

❖ Three-phase classical inverter ($I_{L\_max} = I_{o\_max}$):

$$Vol_1 \propto 3 \cdot \frac{1}{2} \cdot L_f{}^{3/4} \cdot I_{o\_max}{}^{3/2} \tag{34}$$

❖ Three-phase FLI (q = 4):

$$Vol_2 \propto 3q \cdot \frac{1}{2} \cdot L_f{}^{3/4} \cdot I_{L\_max}{}^{3/2} \tag{35}$$

By (4) and (5), the volume ratio is follows:

$$\lambda = \frac{V_{ol2}}{V_{ol1}} = \frac{q^{3/4} \cdot I_{L\_max}{}^{3/2}}{I_{o\_max}{}^{3/2}} = 0.388 \tag{36}$$

Note: $\lambda < 1 \Rightarrow Vol_2 < Vol_1$, so the overall volume is reduced in the case of FLI although many components are required.

V. MODELING AND CONTROL OF THE SYSTEM

A. Output Current Control (External Loop)

By considering the internal resistance of our system's components (filter, cable, transformer and grid), the simplified diagram of the grid-connected FLI is shown in Fig. 6.

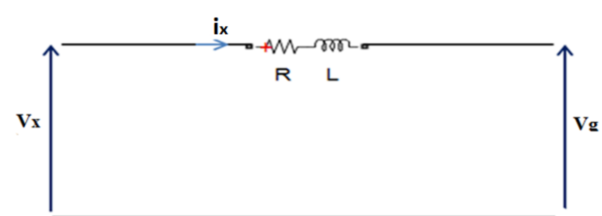

Fig. 6. Simplified connection diagram to the grid [7].

Mathematical models of Fig. 6 are the following:

- In the abc frame:

$$V_x = L\frac{di_x}{dt} + Ri_x + V_g \tag{37}$$

Where V_x , V_g and i_x are the inverter voltage, the grid voltage and the grid current respectively. L is the total inductance ($L = L_f + L_c + L_t + L_g$) whereas R is the total resistance ($R = R_f + R_c + R_t + R_g$).

- In the Park frame:

$$\begin{cases} L\frac{dI_d}{dt} = -RI_d + L\omega I_q + V_d - V_{dg} \\ L\frac{dI_q}{dt} = -RI_q - L\omega I_d + V_q - V_{qg} \end{cases} \quad (38)$$

V_d, V_{dg} and I_d are the d-axis inverter voltage, grid voltage and grid current respectively whereas V_q, V_{qg} and I_q are the q-axis components; ω is the pulsation ($\omega = 2\pi f$).

B. Transfer Function of the Filter

In equation (38), we set [7]:

$$\begin{cases} U_d = L\,\omega I_q + V_d - V_{dg} \\ U_q = -L\omega I_d + V_q - V_{qg} \end{cases} \quad (39)$$

Using the Laplace transform we obtain:

$$\begin{cases} H_d(s) = \frac{I_d(s)}{U_d(s)} = \frac{1}{Ls+R} \\ H_q(s) = \frac{I_q(s)}{U_q(s)} = \frac{1}{Ls+R} \end{cases} \quad (40)$$

The transfer function of the PI controller is given in (41).

$$C\,(s) = k_p + \frac{k_i}{s} \quad (41)$$

Using (38), we calculate the system transfer function $H(s)$ and we do the dq-axis current control loop in Fig. 7. Where, s is the Laplace operator.

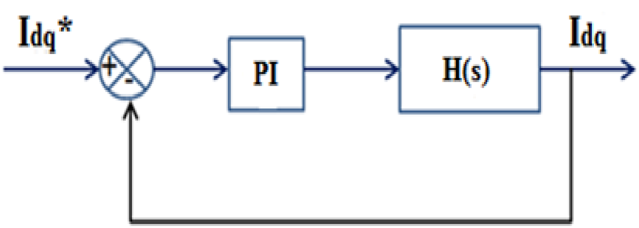

Fig. 7. $\boldsymbol{dq}$-axis current control loop [7].

The system open loop transfer function is given in (42).

$$GO(s) = C\,(s).H(s) = \frac{k_p + \frac{k_i}{s}}{Ls+R} \quad (42)$$

The closed loop transfer function is given in (43).

$$\text{GF}(s) = \frac{GO(s)}{1+GO(s)} = \frac{V_{DC}(k_p s + k_i)/L}{s^2 + \left(\frac{R+k_p}{L}\right)s + \frac{k_i}{L}} \quad (43)$$

C. Calculation of the PI Parameters (k_p, k_i)

The denominator of a second order system is giving in (44).

$$s^2 + 2z\omega_i s + \omega_i^2 \quad (44)$$

By identifying the denominator of (43) with (44), the parameters of the PI controller are obtained in (45) [7].

$$\begin{cases} k_p = 2z\omega_i L - R \\ k_i = L\omega_i^2 \end{cases} \quad (45)$$

Where z is the damping factor, ω_i is the filter pulsation ($\omega_i = \frac{1}{t_i}$; with t_i is the time constant). We consider $z = 0.707$ eliminating the system oscillations.

Using Table 2, we obtain: $L = 2.6$ mH, $R = 1.7\,\Omega$, $t_i = \frac{L}{R} = 1.5$ ms and $\omega_i = 648$ rad.

So the PI controller parameters for the external loop are: $k_p = 0.708$ and $k_i = 1.107 \cdot 10^3$.

D. Control of the Cell Currents (Internal Loop)

The internal loop combined with the Pulse Width Modulation (PWM) bloc is shown in Fig. 8.

Where: i_{ix} are the cell currents whereas $i_{ix}{}^*$ are the references cell currents obtained after inverse Park transform of dq- axis; $i = 1,2..q$ is the cell identifier where q is the number of cells; $V_y{}^*$ is the array of reference voltages obtained after inverse Park transform before balancing; $y = 1,2,3$ is the phase number before balancing And $V_x{}^*$ is the array of reference voltages obtained after balancing operation ($x = a, b, c$ is the phase name).

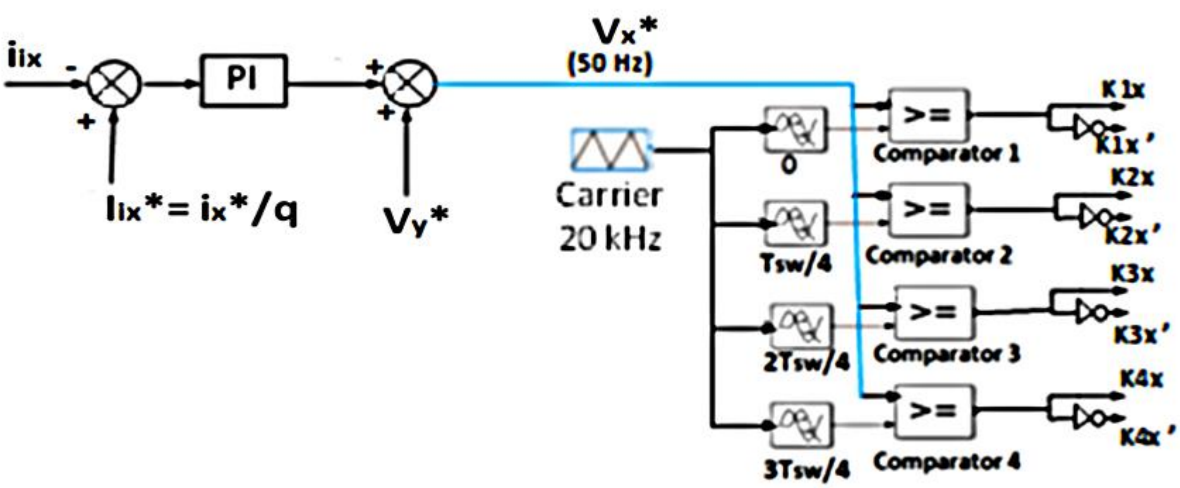

Fig. 8. Internal Loop and $\boldsymbol{PWM}$ bloc.

Our control system can be assimilated to a cascade control with an external loop to control the output current and an internal loop for the cell currents control. In the case of the two cascaded loops, the internal loop must be faster than the external loop [13]. To calculate the PI parameters of the cell currents (internal loop), we have chosen a bandwidth smaller than ten times the switching frequency. We chose a value of $f_i = 2$ kHz for this frequency. Moreover, the damping factor chosen is $z = 0.707$ which gives a fast response without overshooting [14]. The total inductance and resistance values are $L = 2.6$ mH and $= 1.7\ \Omega$. For these parameters and with the defined bandwidth and damping factor values, we calculate the values of the PI parameters (k_{p1} and k_{i1}) by using (45) [14]. So (45) becomes (46).

$$\begin{cases} k_{p1} = 2z\omega_{i1}L - R \\ k_{i1} = L{\omega_{i1}}^2 \end{cases} \tag{46}$$

Were $\omega_{i1} = 2\pi f_i$ is the pulsation corresponding to the bandwidth; k_{p1} and k_{i1} are the PI parameters for the internal loop. We obtain $k_{p1} = 45.22$ and $k_{i1} = 4.17 \cdot 10^5$.

VI. Simulation Results and Discussion

The simulation is done using Matlab Simulink and SimPower Systems by considering the specifications given in Table 2.

So in order to test the developed control, we set

$Q^* = 0$ and P^* is varied on time (t) as follows:

- for $t \in [0\ 1]$ s, $P^* = 5.2$ kW
- for $t \in [1\ 2]$ s, $P^* = 3.2$ kW
- and for $t \in [2\ 3]$ s, $P^* = 5.2$ kW.

Where Q^* and P^* are the reactive and active power references respectively.

Some simulation results are shown in Fig. 8 to 14. We can see in Fig. 8 that the current waveform varies according to P^*. This is normal because by varying P^* we indirectly vary the current (${i_{abc}}^*$) (This variation is also noticeable in Fig. 9 and 10). Thus, the developed control tracks the references and can be validated.

Fig. 9 and 10 show the waveforms of the cell currents without and with balancing respectively. The balancing of cell currents is necessary to evenly distribute the output current between the different cells in order to increase the reliability of the system [4], [5], [14]. Note that the output current is equal to q times the cell current ($i_x = q \cdot i_{ix}$).

Fig. 11 shows the waveform of the three-phase grid voltage where we can see that the voltage is sinusoidal and smooth. Therefore, our system injects current into the grid without disturbing it.

To check the condition of current frequency and grid frequency matching, we need a Phase Locked Loop (PLL) to synchronize our system with the grid [6]. Fig. 12 shows the superposition of the injected current into the grid of the phase a, on the simple grid voltage curve of the same phase. We can see that the current (i_a) and the grid voltage (V_a) are in phase and have the same frequency (50 Hz).

Fig. 13 shows the current and voltage Total Harmonic Distortion (THD). The THD of the current is equal to 2.82 % (cf. Fig. 13(a)) whereas the THD of the voltage is equal to 3.56 % (cf. Fig. 13(b)). Both THD respect the IEE1547 standard which requires THD to be smaller than 5 % for the first 50 harmonics [10].

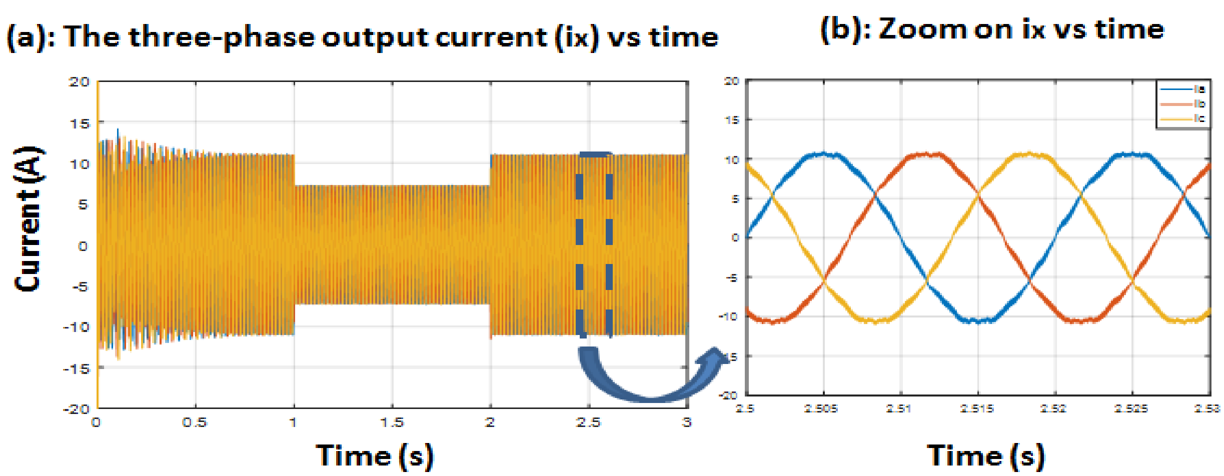

Fig. 9. Three phase output current ($\boldsymbol{i_{abc}}$).

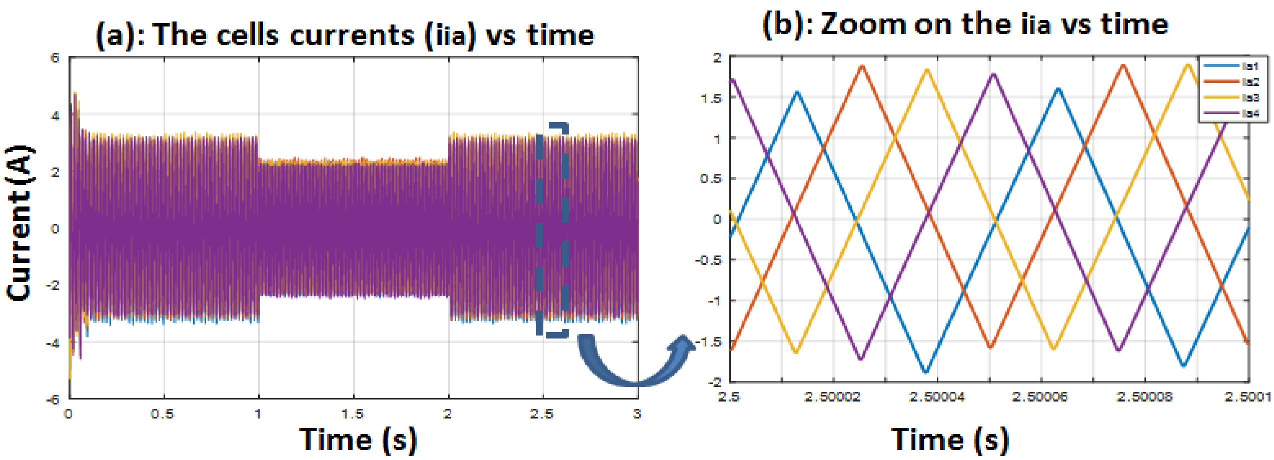

Fig. 10. Unbalanced cells currents ($\boldsymbol{i_{ia}}$) for one phase.

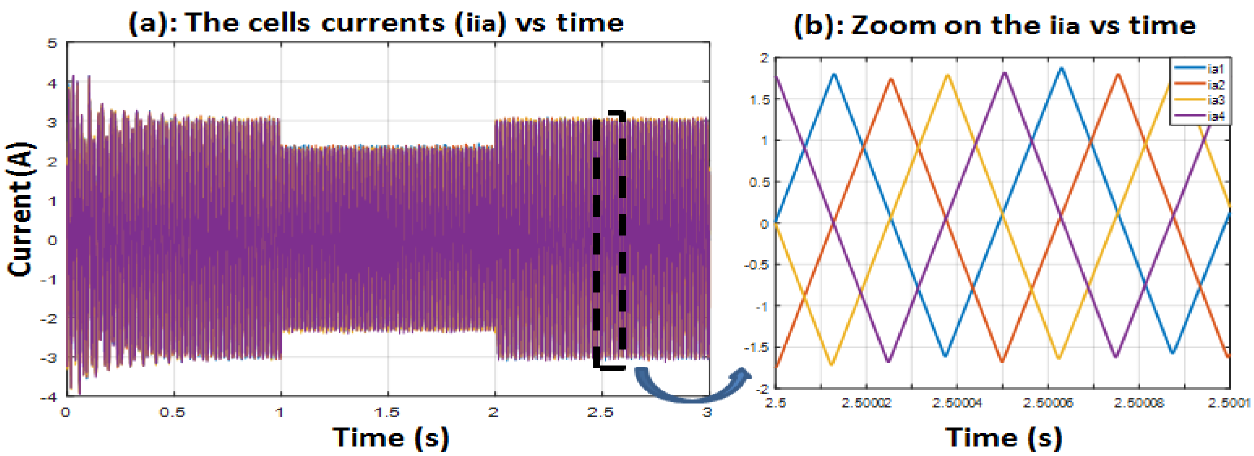

Fig. 11. Balanced cells currents (i_{ia}) for one phase.

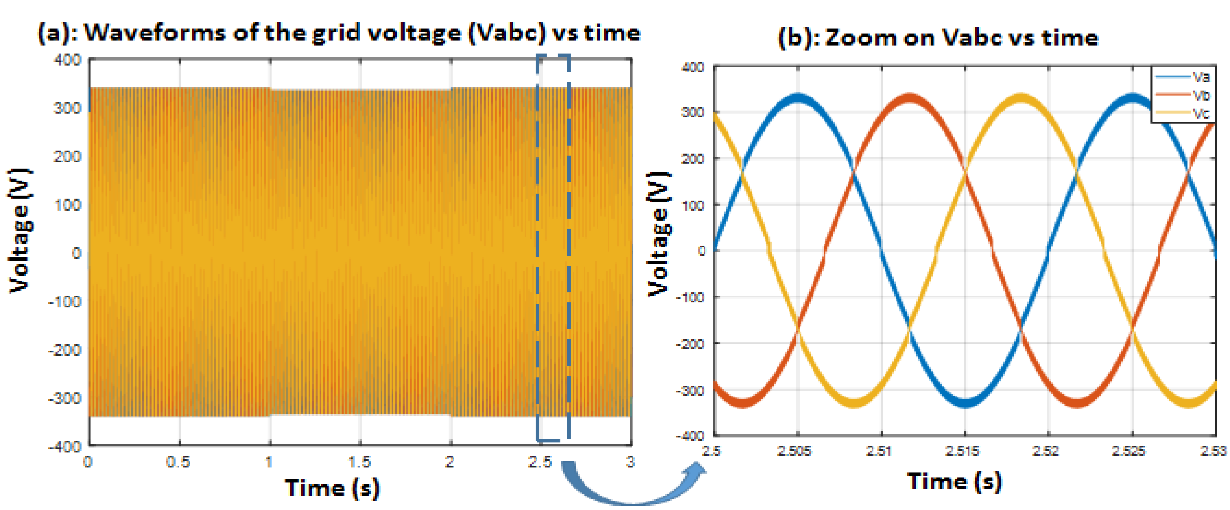

Fig. 12. Waveform of the inerter output voltage.

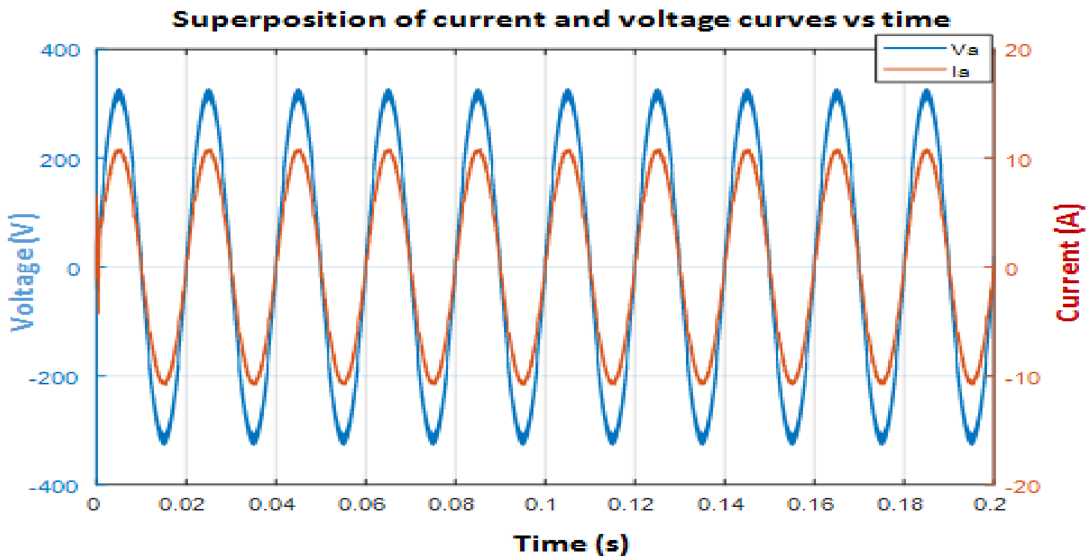

Fig. 13. PLL simulation result.

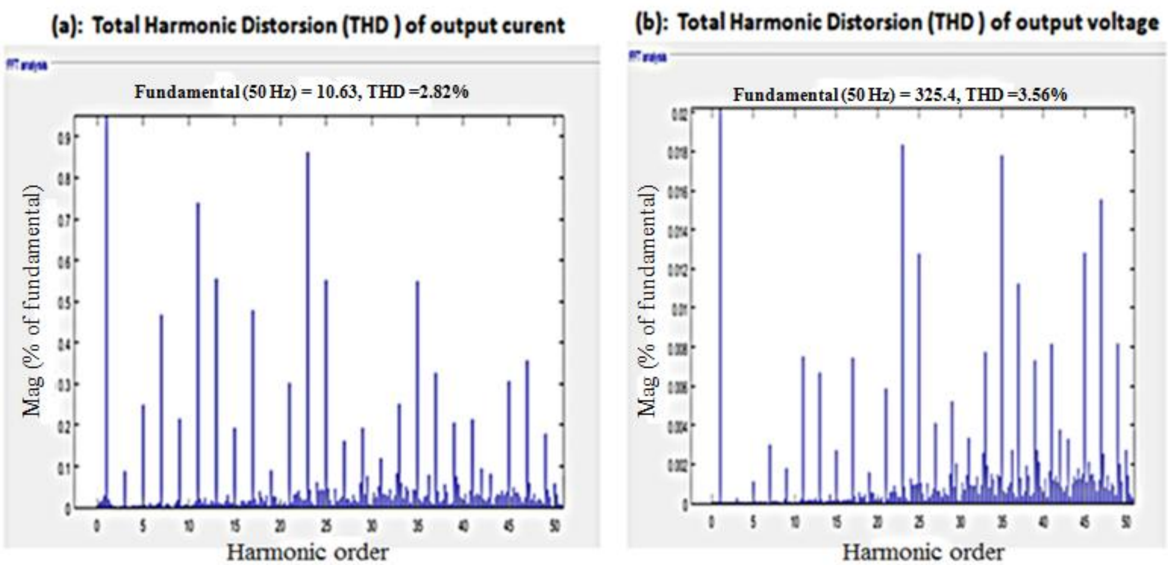

Fig. 14. Frequency analysis curves.

VII. Conclusion

The sizing of passive elements and simulation results showed the value of the FLI converter. The strengths of this inverter are the quality of the waveforms (see Fig. 3), the reliability of the system obtained by using several cells and the reduction of the output filter volume. The developed balanced PQ - control allowed to follow the instructions while balancing the currents flowing through the switching cells of the FLI. The balancing of cells currents is very important to increase the reliability of the system. The interleaved L - filter has been sized to obtain a current THD equal to 2.82 % and a voltage THD equal to 3.56 %.

However, the disadvantage of the proposed architecture is the number of semiconductors used to make the FLI. Fortunately, this disadvantage can be mitigated by the reliability of the system and the low price of the semiconductors [7].

In the future, it would be interesting to take into account the impact of the neighbor's consumption on our system.

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Redundancy Level Impact of the Mean Time to Failure on Wireless Sensor Network

Alaa E. S. Ahmed
[1]College of Computer and Information Sciences,
Al Imam Mohammad Ibn Saud Islamic University (IMSIU)
Riyadh, Kingdom of Saudi Arabia
[2] Department of Electrical Engineering,
Faculty of Engineering (Shoubra), Benha University, Egypt

Mostafa E. A. Ibrahim
[1]College of Computer and Information Sciences,
Al Imam Mohammad Ibn Saud Islamic University (IMSIU)
Riyadh, Kingdom of Saudi Arabia
[2]Communication and Computer Engineering Dept,
Benha Faculty of Engineering, Benha University, Egypt

***Abstract*—Recently, wireless sensor networks (WSNs) have gained a great attention due to their ability to monitor various environments, such as temperature, pressure sound, etc. They are constructed from a large number of sensor nodes with computation and communication abilities. Most probably, sensors are deployed in an uncontrolled environment and hence their failures are inevitable all times of work. Faulty sensor nodes may cause incorrect sensing data, wrong data computation or even incorrect communication. Achieving a reliable wireless sensor networks is a most needed goal to ensure quality of service whether at deployment time or during normal operation. While Nodes redundancy is considered as an effective solution to overcome nodes failures, it may negatively affect the WSN lifetime. Redundancy may lead to more energy drains of the whole system. In this paper, the impact of redundancy level on the Mean Time to Failure (MTTF) of a clustered based wireless Sensor Networks (WSNs) is investigated. An expression that can be used to determine the most suitable redundancy level that maximizes the network MTTF is derived and evaluated.**

Keywords—Wireless sensor network; reliability; clustering; fault tolerant; Mean Time to Failure (MTTF)

I. Introduction

Wireless sensor networks (WSNs) are currently being considered for many communications applications, such as environmental monitoring, agricultural monitoring, machine health monitoring, surveillance, and medical monitoring. These networks provide a great ability to better understand the surrounding physical phenomenon and translate their effect to be analyzed to give a more accurate way to control our surroundings. However, there are many research QoS challenges that need to be studied and analyzed to achieve scalable reliable and dependable networks.

Traditionally, redundancy is a technique belongs to replica management approaches which are designed to overcome nodes failure and to achieve reliable system. Redundancy most probably leads to maximize the availability of the nodes.

In sensor networks, sensor nodes can fail due to many reasons. Among those reasons are: battery power depletion, hardware problem and cruel environmental circumstances in which the node is running. Nods are failed according to a variable failure rate that start by a low value and continuously increase and may reach to value that cause a complete failure to the system. One solution to overcome nodes failure is to use reliable hardware that safely send, receive and store data. This solution is expensive solution that contradicts with the objective of having cheap wireless sensor. Replicating data on spatially separated nodes is a good method for minimized the failure probability. Traditional solutions for replica systems are to use a pre-determined fixed number of replicas [1].

Because of the dynamic behavior of failure, selecting a suitable redundancy level is an important issue. In some cases small number of replicas is better and on the other hand in some situations higher number of replicas is more suitable. Because of that, the process of selecting the suitable redundancy level should be adaptive to achieve less energy consumption and higher degree of availability. One way to determine the most suitable redundancy level is to have a complete knowledge of the network which is not a practical solution and doesn't cope with scalability issue. Also, it requires much information to be circulated around the network to keep up to date with the current situation which consumes more energy. The solution is to find a solution to determine the most suitable redundancy level that achieves a reliable request while maximizing the Mean Time to Failure MTTF of the system. The contribution in this paper is as follows:

1) Describe a system model that captures all stages that affect the energy consumption l of entire the network.

2) Propose an expression that is used to determine the most suitable redundancy level to maximize the mean time to failure MTTF.

3) Provide a numerical data analysis that implements the proposed model to show the tradeoff between the energy consumption and the reliability improvement.

The remainder of the paper is organized as follows: In Section 2, the related work is introduced. The system model assumptions are presented in Section 3. Section 4 shows the analysis and numerical results. Finally, the paper ends with the conclusion in Section 5.

II. Related Work

The general problem of achieving reliable WSN has been covered intensively in literature. Providing the concept of redundancy is considered an efficient trend in order to achieve reliable wireless sensor network. Redundancy types can be subdivided into three categories, spatial redundancy, physical redundancy and temporal redundancy.

Spatial redundancy is based on geographically distribute the sensor nodes over the field area in such a way that guarantee the replication of the resources all over the coverage area. Spatial redundancy is suitable for WSN since the information read by any sensor node is available and stored in other different nodes. This kind of redundancy can be used in implementing fault tolerant approached to improve the WSN reliability level. Spatial redundancy is drawn by large number of metrics [2], [3]. In [4] authors employed the graph theory and cut sets in order to define the redundancy degree of the wireless sensor network. It is the most possible number of nodes that its disappearance doesn't affect the accuracy of the measured data.

Physical redundancy is a hardware redundancy and is considered one of the easiest ways to achieve reliable systems. It is mainly based on having a dense number of independent sensor nodes to be distributed and cover certain filed area [5], [6].

Temporal redundancy is mostly used to get better accuracy of the sensor nodes readings and to overcome the transient failures. In Wireless sensor networks, the reading come from any single node may be not precise. The solution is to improve the whole system reliability by using multiple reading from the same sensor node [7].

In [8] authors present a method for evaluating the system reliability by generating a fault tree for the whole network at the time of failure occurrence. The provided solution is independent of the underlying network technology. However, the model doesn't take the energy consumption into consideration.

In [9], [10] a power consumption saving approach is introduced. Power consumption saving is considered one way of achieving reliable wireless sensor network. The approach adopts the use of Colored Petri Net to model the network and provide a good way to be integrated with different applications.

In [11] authors present an efficient method that could be used in transmitting the data through the WSN. The method is mainly tends to minimize the number of lost packets by using multiples paths for data transmissions to overcome either the node or the path failure. One problem with this method is the bottleneck produced as a result of having more than one path per packets.

Clustering is one of the most used techniques in reducing the energy consumption in WSNs and consequently increase the sensor node life time. One of the earliest WS communication algorithms is LEACH [12]. It stands for Low Energy Adaptive Clustering Hierarchy Algorithm. The existence of clustering leads to minimize the energy usage with the cluster but at the same time accelerate the energy consumption of the cluster head CH. To solve this problem, the concept of balanced clustering is introduced in [13]. Another cluster based approach called Distributed Weight-Based Energy-Efficient Hierarchical Clustering (DWEHC) is introduced in [14]. It is based on forming well balanced clusters by adopting the hierarchical level of a node depending with the ability to minimize the energy requirements by taking into consideration two factors, the range of a cluster and the path to the CH.

In [15] energy an Energy-Efficient Unequal Clustering (EEUC) mechanism is introduced. It is based on dividing the nodes into unequal cluster sized. This technique is dynamic in the sense that, it picks any node randomly and checks whether it lies within the competitive radius or not. So, the node would join the most suitable cluster that saves its energy. A lot of energy-efficient clustering algorithms can be found is available in [16].

III. System Model Assumptions

In this section, we describe the proposed system model and its assumptions. The network is formed by a collection of limited-energy Sensor Nodes (SNs) scattered randomly on a certain geographical area. The WSN model used in this work is adopted from [17].

1) Initially each sensor node has an initial energy E_{init}.

2) The sensor nodes are scattered randomly through a square field area.

3) It is assumed that each node has failure probability f(t) where (where $0<f(t)<1$).

4) LEACH algorithm [11] is used for routing and managing the network clustering. First the cluster head "CH" is elected per cluster. The CH is responsible for administrating the communication within the cluster, aggregate data read by sensors nodes, and set up the data sent to the sink nodes. This algorithm runs in the form of rounds. Due to the extra responsibilities of the CH node, it is exposed to lose their energy quicker than other nodes. For this reason, the CH role is rotated around all member of the cluster according to a certain probability p. the value of p depends on the cluster size.

5) In this model it is assumed that the communication channels are reliable and never fail.

6) It is assumed that the reliability of the system is expressed as follow [18].

$$\mathrm{R}_{m-of-n} = \sum_{i=0}^{N-M} \binom{N}{\mathrm{i}} \left(1 - R(t)\right)^{i} R(t)^{N-i}$$

$$= \sum_{i=M}^{N} \binom{N}{\mathrm{i}} R(t)^{i} (1 - R(t))^{N-i} \tag{1}$$

$$\text{Where,} \quad \binom{N}{\mathrm{i}} = \frac{\mathrm{N!}}{\mathrm{i!\,(N-i)!}}$$

Where, N is the number of identical sensor nodes per cluster

m = the number of functional nodes

R(t) = the reliability of individual module.

$R_{m\text{-}of\text{-}N(t)}$ is the reliability of that (N-m) or fewer nodes have failed by time t (or – at least m are functional).

7) In response to a request, a sensor node sends a message to its CH node. It is assumed that the number of hops between the sensor node and the cluster head is N_{clust}. Any request needs "m" sensor nodes to reach a certain redundancy level. The total energy E_t for any request has two components E_1 and E_2. The first is the energy consumed to send the data from sensor node to the CH and the other is the energy consumed by the WSN to transmit sensor data from CH to the sink node. The total energy equation can be expressed as follow [17]:

$$E_t = E_1 + E_2 \quad (2)$$

$$E_t = [N_{hop} (E_{receive} + E_{transmit})] + [m(E_{receive} + E_{transmit}) + N_{clust} (E_i)] \quad (3)$$

8) The energy consumed in executing the clustering process includes the amount of energy due to multicasting the leadership announcement message and the energy due to joining the cluster. If p is the probability of becoming a CH, there will be $p*N_{clust}$ sensor node that multicast the leadership announcement message which in turn is forwarded by each sensor to the next hop until covering the whole nodes in the cluster. Assume the number of hops per cluster is $_{Nhop/cluster}$ Thus, the energy required for broadcasting is [17]:

$$E_{br} = pN_{clust}(E_{receive} + E_{transmit}) + N_{hop/cluster}((E_{receive} + E_{transmit}) \quad (4)$$

9) The energy consumed due to the cluster-join process includes the energy consumed by any sensor node to inform the CH about their cluster membership and the energy consumed by the CH to send back an acknowledge message to the sensor nodes.

$$E_{join} = N_{clust} (E_{receive} + E_{transmit}). \quad (5)$$

10) Since the clustering process is executed a number of rounds "N_{round}" then the total energy consumed in clustering is expressed as [17]:

$$E_{clustering} = N_{round} [E_{br} + E_{join}] \quad (6)$$

IV. System MTTF

The main objective here is to achieve the most suitable redundancy level m that achieves a reliable request while maximizing the Mean Time to Failure MTTF. Assume it is required to process a request with required reliability Rq. Assume λ is the failure rate of different sensor nodes. Since we use m out of N reliability model, the MTTF can be calculated according to the following:

Since, $\mathrm{MTTF}_{\mathrm{m\ of\ N}} = \int_0^\infty \mathrm{R}_{\mathrm{m\ of\ n}}$

By substituting from (1):

$$\mathrm{MTTF}_{\mathrm{m\ of\ N}} = \int_0^\infty [\sum_{i=m}^{N} \binom{N}{i} R(t)^i (1 - R(t))^{N-i}] dt$$

$$\mathrm{MTTF}_{\mathrm{m\ of\ N}} = \int_0^\infty [\sum_{i=m}^{N} \binom{N}{i} e^{-i\lambda t} (1 - e^{-\lambda t})^{N-i} \quad] dt$$

By introducing $v = e^{-\lambda t}$ we obtain $dv = \lambda\, e^{-\lambda t} dt$ → $dt = \frac{dv}{\lambda\, e^{-\lambda t}}$ dv

By substituting in the MTTF m of n

$$\mathrm{MTTF}_{\mathrm{m\ of\ N}} = \sum_{i=m}^{N} \binom{N}{i} \int_0^1 \frac{v^i (1-v)^{N-i}\ dv}{\lambda v}$$

$$\mathrm{MTTF}_{\mathrm{m\ of\ N}} = \sum_{i=m}^{N} \binom{N}{i} \frac{1}{\lambda} \int_0^1 [v^{i-1} (1-v)^{N-i} \quad] dv$$

According to Gamma and Beta function definition [18]:

$$\int_0^1 [v^{i-1} (1-v)^{N-i} \quad] dv \quad = \frac{\Gamma(i)\Gamma(n-i+1)}{\Gamma(n+1)}$$

So,

$$\mathrm{MTTF}_{\mathrm{m\ of\ N}} = \sum_{i=m}^{N} \binom{N}{i} \frac{1}{\lambda} \frac{\Gamma(i)\Gamma(n-i+1)}{\Gamma(n+1)}$$

And consequently,

$$\mathrm{MTTF}_{\mathrm{m\ of\ N}} = \sum_{i=m}^{N} \binom{N}{i} \frac{1}{\lambda} \frac{(i-1)!\,(n-i)!}{(n)!}$$

Then,

$$\mathrm{MTTF}_{\mathrm{m\ of\ N}} = \frac{1}{\lambda} \sum_{i=m}^{N} \frac{n!}{i!\,(n-i)!} \frac{(i-1)!\,(n-i)!}{(n)!}$$

Finally,

$$\mathrm{MTTF}_{\mathrm{m\ of\ N}} = \frac{1}{\lambda} \sum_{i=m}^{N} \frac{1}{i} \quad (7)$$

V. Analysis and Numerical Results

In this section we introduce the numeric data analysis that implements the proposed model to show the tradeoff between the energy consumption and the reliability improvement. Also, we show the effect of changing m on the MTTF of the system. The following paragraph indicates parameters used along with their default parameters. These default values are similar to the values used in [33]. The WSN model consists of 400 sensor nodes distributed randomly in a square area of 200m by 200m. Each sensor node has an initial energy of 10 Joule. The energy consumed per bit due to the transmitter/receiver radio process- $E_{receive}$ & $E_{transmit}$ - is 50nJ/bit.

A. Reliability and MTTF Analysis

Fig. 1 shows the relation between the reliability and the redundancy level m under the environment parameters described in the previous paragraph. It is possible to use other parameter but still the overall trend is the same. In previous chapter the reliability analysis is based on adopting and applying the N out of m redundant systems to achieve a reliable WSN. The N sensor nodes are assumed to be identical in all configurations. The N out of m redundant system is considered a sort of parallel system where m represents the minimum number of sensors per cluster required to have a fully functional sensing operation during certain time period T. we assume that sensor failure may occur according to a failure rate λ = .001 and T = 200 unit time. In case m =1 the system is reduced to a fully parallel system since any single node will do the job. On the other hand when m = N, this means that the system is act as a series system since the all members in the cluster are required to have a correct operation. From that Fig. 1 shows the relation between the system reliability and the m value through out a certain period of time according to (1). The graph show that as the m value increases the reliability level is reduced. This result consistent with the fact that says as m increase the system tends to converge to a series one. The overall reliability of series systems is lower than the reliability of each individual component. At the same time as the m value decrease the system tends to converge to be a parallel one that ha reliability an improved reliability level.

As a consequence of the previous result, Fig. 2 shows the relation between the m value and the MTTF (8). The result shows that the MTTF is decreased as m increase. This result is compatible with the result achieved in Fig. 1. As the system tends to be fully parallel, the MTTF increase since the reliability increases.

The following two figures (Fig. 3 and 4) shows the relation between both the system reliability and the MTTF and the m value but with failure rate = .0001 and T = 200 unit time. The figure shows the same trend achieved in Fig. 1 and 2.

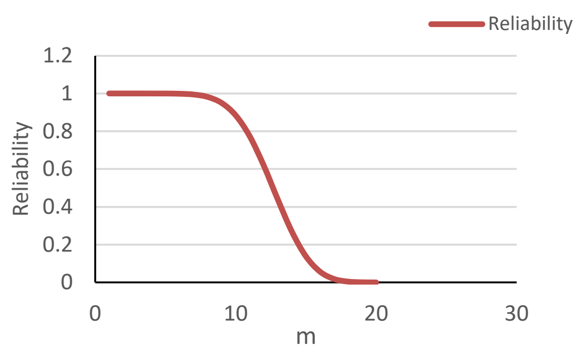

Fig. 1. Reliability VSm with λ = .001.

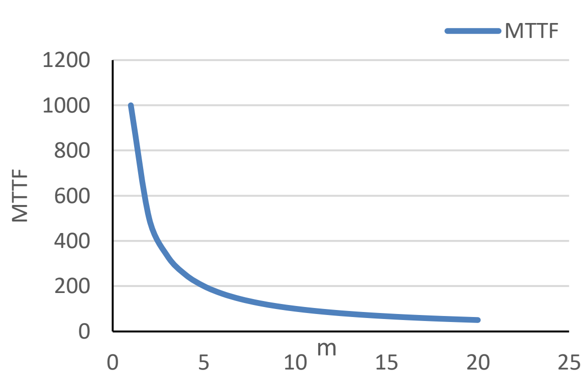

Fig. 2. MTTF VS m with λ = .001.

B. Energy Level Consumed Analysis

In this section we introduce the numerical analysis related to the level of consumed energy of due to applying the m out of n redundant system. Fig. 5 shows the relation between the energy consumed as a result of 24 bits size request. The figure shows three curves that represent the consumed energy level with different value of the number of intermediate nodes within the cluster (N_{clust}). As the value of m increase the energy consumed increase. This result is compatible with the fact that as m increase, the system tends to work as a series fashion that involve more sensor nodes in the process of completing the request. As the number of involved sensors increase the energy consumed will increase.

Also, Fig. 6 shows the relation between the m value and the consumed energy in the case of changing the parameter of the number of nodes exists between the cluster head and the sink node (N_{hop}). The result indicates that as m value increase the energy consumed increase even with different values of N_{hop}.

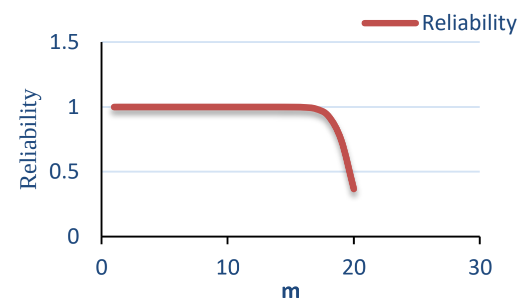

Fig. 3. Reliability VS m with λ = .0001.

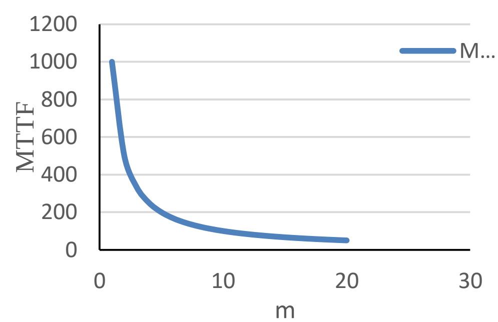

Fig. 4. MTTF VS m with λ = .0001.

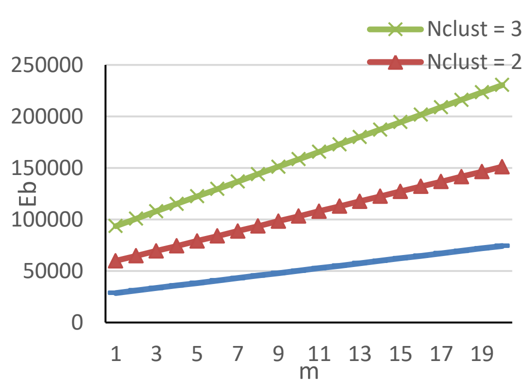

Fig. 5. 5Eb VS m with λ = .001.

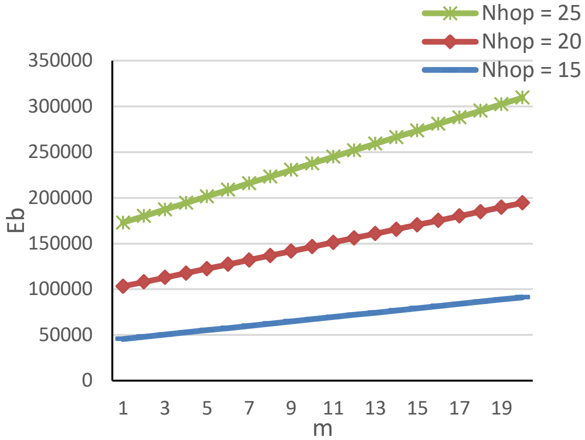

Fig. 6. E_t VS m with λ = .0001.

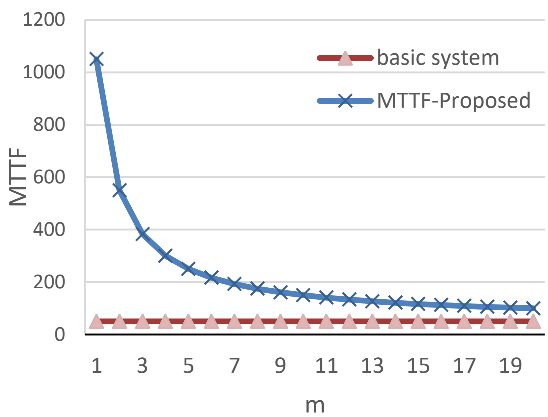

Fig. 7. MTTF VS m with λ = .001.

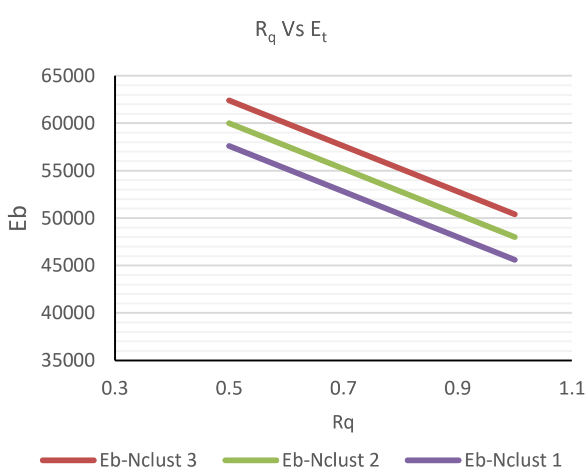

Fig. 8. Et vs Rq with λ = .001.

C. Comparison with the Basic System (m = 1)

In this section we compare the MTTF for both proposed design and the basic system in which there is no redundancy at all. Fig. 7 shows the change of the MTTF in both the basic system and the proposed design. We notice that the proposed system give higher system MTTF compared with the basic design under the set of assumed parameter values characterizing the WSN.

D. Consumed Energy Effect on the Required Reliability Level

One of the important parameters that is useful to the WSN designer is to be able to determine the energy consumed Et when a required level of reliability R_q is needed to be satisfied. Fig. 8 shows the relation between the R_q and Et under the set of assumed parameter values characterizing the WSN.

According to the proposed model, as the required the reliability level increase the number of active nodes per cluster m decrease and that would cause the energy consumed to decrease. This result is shown in Fig. 8. That would consequently help the system designer is able to have a tentative estimation about the energy consumed for the required and needed system reliability level. One more result shown in the figure is that as the number of intermediate nodes within the cluster N_{clust} increase the energy consumed per certain required reliability increase.

VI. Conclusions

In this paper, a probability model to calculate the system reliability, the energy Consumption of a request, and, consequently, the system MTTF is introduced. Throughout the model we considered energy consumed by the sensor nodes due to request processing, periodic status update processing and cluster formation. The proposed model is adopting a group communication service represented of forming, managing and using the cluster. The effect of the redundancy level on MTTF is evaluated. A series of numerical analysis result that show and validate the proposed model showing the reliability, MTTF and energy consumed in order to achieve a dependent WSN system are conducted. As a conclusion, the MTTF of the system increase as the number of active components m per cluster decrease. Also, the m parameter could be used as design parameter that helps the designer to achieve a system with a required level of reliability.

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Bi-Objective Task Scheduling in Cloud Computing using Chaotic Bat Algorithm

Fereshteh Ershad Farkar
Department of Computer Engineering,
Tabriz Branch, Islamic Azad University,
Tabriz, Iran

Ali Asghar Pourhaji Kazem*
Department of Computer Engineering
Tabriz Branch, Islamic Azad University,
Tabriz, Iran

***Abstract*—Cloud computing is a technology for providing services over the Internet. It gives approach to renting IT infrastructures on a short-term pay- per-usage basis. One of the service provider's goals is to use the resources efficiently and gain maximum profit. Cloud processes a huge amount of data, so tasks scheduling is a vital role in the cloud computing. The purpose of this paper is to propose a method based on chaos theory and bat algorithm for task scheduling in Cloud computing. Task scheduling is a core and challenging issue in cloud computing. The nature of the scheduling issue is as an NP-Hard problem and because of the success of heuristic algorithms in optimization and NP-Hard problems, the authors use a newly inspired bat algorithm and chaos theory to scheduling the tasks in the cloud. In this method, bat or candidate solutions are represented by a one-dimensional array. The fitness function is calculated based on makespan and energy consumption. The results show that the proposed method can schedule the received tasks in proper time than other compared heuristic algorithms, also the proposed method has better performance in term of makespan and energy consumption than compared methods.**

***Keywords*—Cloud computing; scheduling; chaos theory; bat algorithm**

I. Introduction

Cloud computing (a recent computing model) comes from distributed computing, parallel computing and grid computing. The dynamism and heterogeneity are properties of cloud computing resources. In cloud computing, resources such as storage, memory, processors, and applications are provision as services. Cloud computing environment is a commercial platform. Currently, there exist many commercial clouds, such as Amazon, which provide virtualized computational and storage hardware. Virtual Machine (VM) is a critical component of software stacks in the cloud computing, for example, Amazon Elastic Computing Cloud (Amazon EC2) [1] is a cloud platform that provides infrastructure as service in the form of VMs. The cloud computing greatly decreases the financial cost of acquiring hardware and software for application deployment, as well as maintenance costs [2]. So, how to use efficiently and effectively cloud computing resources becomes more important. Cloud computing provides a pool of resources in a self-service, dynamically scalable and metered method with guaranteed quality of service to users. To achieve guaranteed Quality of Service (QoS) to users, that is important the tasks be assigned efficiently to defined resources by providing multiple VMs for executing the tasks included in a program. Cloud computing also offers pay-per-use metered service. There are motivational research results for efficient task scheduling in cloud computing, but task scheduling problems are still considering as an NP-complete issue. There are some objective functions and optimization criteria while tasks scheduling in the cloud environment, such as makespan, cost, flow time, tardiness, waiting time, turnaround time [3], and energy consumption [4]. In our proposed work, we propose QoS-based task scheduling algorithm called the Chaotic Bat Algorithm for task scheduling on cloud computing, which aims to create a schedule to minimize the total makespan and energy consumption of tasks executions. Bat algorithm, first proposed by Xing-She Yang [5], is a new meta-heuristic algorithm inspired by the echolocation of micro-bats to sense distances while detecting their prey. Micro-bats using this technique can find their prey and recognizes prey even in complete darkness Echolocation is the main specification of bats behavior. This means that the bat gives out sound pulses and listens to echoes to find preys and avoid collisions obstacles while flying. The Bat algorithm can have superiority performance than optimization algorithms and can solve many problems, including real world and practical engineering optimization problems [6]. So one aim of this paper is to introduce chaos into the standard bat algorithm.

The rest of the paper is classified as follows: Section 2 is talking about related work for scheduling in cloud computing; Section 3 includes the background, classical Bat Algorithm and Chaos Theory; Section 4 describes the problem; Section 5 discusses the main idea and how the new Bat Algorithm and Chaos Theory are integrated; Section 6 contains the simulations and results obtained; and Section 7 tells about the future scope and conclusion of this paper.

II. Related Works

Task scheduling is a critical issue in cloud computing, so a lot of researches have been done in this scope. This problem is of a known Np-Hard type issue [2], [4], [7]-[9]. They belong Np-Hard including thousands of different issues with many applications. So far, no solution has been found for these issues in a reasonable time, and may not be found in the future at all. These also prove that there is no quick solution for them. If a solution found only for any of these issues, this solution would solve the most parts of such this issues. Solution based techniques on full search are not feasible for this kind of problems. The cost of schedules is very high. Metaheuristic-based techniques can overcome these problems

*Corresponding author

by providing near optimal solutions in reasonable time. For example, ACO algorithm is useful for solving separate optimization problems which requiring one path to reach a goal. It has been successfully for solving multidimensional knapsack problem, traveling salesman problem, job shop scheduling, and quadratic assignment problem, task scheduling in grid and cloud computing, and much more [3]. In [10], they have considered minimization of makespan as the objective function. Their objective function based on execution time and transfer time of tasks on VMs. The algorithm simulated with the number of tasks changing from 100 to 1000 in the cloudsim simulation environment. ACO has been compared with RR and FCFS algorithms and experimental results show that when the number of tasks increased, ACO execution gets a short time compared with RR and FCFS. For 1000 tasks, the algorithm able to decrease makespan in comparison with RR and FCFS. Recently, the genetic algorithm is useful metaheuristic for taking high-quality solutions for combinatorial optimization problems, including the task scheduling problem [11]. Another competency of genetics is that its inherent parallelism can activate to reduce running time [12].

III. BACKGRPOUND

A. Bat Algorithm

The bat algorithm has been a recently proposed metaheuristic algorithm by Xin-She Yang [5], based on the echolocation of micro bats. In the real world, echolocation can diffuse within only a few thousandths of a second with a changing frequency. Micro bats use echolocation to search preys. All micro bats are insectivores and they use a type of sonar, called echolocation, to find preys and avoid obstacles. Now, we remind the standard bat algorithm according to the following rules:

All bats use echolocation to sense distance and find prey, also they know the difference of food and obstacles with some magical method.

Bats fly randomly with velocity V_i at location X_i with a permanent frequency Fmin, Fmax changing loudness A_0 and wave length λ to search prey. They can intelligently tune the wavelength (or frequency) of their emitted pulses and tune the rate of pulse emission $r \in [0, 1]$, relevant on the proximity of their aim.

Although the loudness can change in many ways, we consider that the loudness changes from positive A_0 to a minimum fixed value A_{min}.

Initialize solutions: the virtual bats (solutions) have the positions X_i, and velocities V_i in a D-dimensional search space. They are randomly distributed in the possible search space.

Generate new solutions: the values of the frequency F_{min} and F_{max} is dependent on the dimensions of the issue. The positions and velocities of bats in every temporal interval are defined as follows:

$$f_i = f_{min} + (f_{max} - f_{min}) \times \beta , \quad (1)$$

$$v_i^{t+1} = v_i^t + (x_i^t - x_*) \times \beta , \quad (2)$$

$$x_i^{t+1} = x_i^t + v_i^{t+1} \quad (3)$$

Where $\beta \in [0,1]$ is a random vector and X_* is the current global best solution.

Local search: create a random number. If it is bigger than the i[th] bat pulse emission rate *(r_i)*, then create the new bat. A new solution is generated around the current best solution

$$\text{If rand} > r_i \quad (4)$$

$$X_{new} = X_{old} + \varepsilon * A_{mean}^t .$$

Where $\varepsilon \in [-1, 1]$ is a random vector and A_t is the average loudness of all bats at time step t. r_i is the i[th] solution pulse emotion rate.

Updating solutions by flying randomly: loudness is reduced and pulse emission rate is increased by using the equations as follows:

$$\text{If rand () } < A_i \;\&\&\; f(x_i) < f(x_*),$$

$$F(x) = f(x_i), \quad (5)$$

$$A_i^{t+1} = \alpha A_i^t$$

$$r_i^{t+1} = r_i (1 - \exp(-\gamma t))$$

Where α and $\gamma \epsilon [0, 1]$, A_i is the i[th] bat loudness *(x_i)* is the fitness value of i[th] bat and $f(x_*)$ is fitness value of the best bat.Update the current global best solution by described the formulas until reached the termination condition.

B. Chaos Theory

In this world numbers are essential for seeing most natural phenomena, our surrounding world isn't a static system and this system change with the dynamism of time. When system change, the numbers represent system state in a temporal step. The dynamic systems have not a lawful period for representing the system states with numbers. The system can change in discrete time. For example, all animals and most of the insects have a one-year life cycle, and study of them requires that only we look on their life system once in a year. These systems are known as non-linear systems. In such systems, the system output is not proportional to the input. If variables changes in an initial time result may change of the same or another variable time. Therefore, the system changes are not proportional with the systems input. The non-linear systems could not be divided into smaller sections and be solved separately. They possess complete complexities. In non-linear sciences, non-linear dynamic systems are studied. Nature is a non-linear system. The non-linear systems are employed in studying various fields, such as Mathematics, Biology, Physics, Chemistry, and Computer sciences. Furthermore, the chaotic systems are very sensitive to initial values, and a small change in the initial values will have great changes in the output. The changes of dynamic systems in the discrete time called a map. In another discussion, the convergence of evolutional algorithms is mainly dependent on the initialization of its parameters. When the random parameters are used for initialization, different results are seen in various executions of this algorithm. For this reason, the

[*]Corresponding author

random variables are a key which may lead the algorithm to escape from local optimum to better results. Some chaotic maps are well known and we can use them in the algorithm parameters initialization, such as Gauss Map, Tent map, Circle map, Iterative map, logistic map, Sinusoidal map.

IV. Problem Definition

A. System Model

Cloud computing environment is used virtualization to map the resources to the virtual machines. The tasks classify according to QoS requirement, such as bandwidth, cost, resource distance, credibility Finally, schedule the tasks to physical resources. This paper intends that when virtual resources meet tasks QoS requirement, using makespan and energy-aware algorithm schedule tasks to physical resources.

B. Resources and Tasks

R= $\{R_1, R_2 \dots R_n\}$ represents a set of resources, where R_i is the ith resource. Each resource implemented with a Dynamic Voltage scaling module [4]. If supply voltage and frequency decrease, it causes to reduce the energy consumption consumed by the resource. Resource R_i represented as R_i {rcc, svs} where rcc is the resource computing capacity parameter of R_i, svs is the supply voltage strategy of ri. In svs, there is a relational vector between its supply power and frequency. That is $V_i=[\{vs_1(i),fs_1(i)\};\{vs_2(i), fs_2(i)\};\dots;\{vs_l(max)(i),fs_l(max)(i)\}]$, where $vs_l(i)$ supplies power of resource R_i at DVS level s_l, $fs_l(i)$ is the relative frequency coefficient within the range of [0,1]. In this paper, we represent 3 power supply strategies (voltage and relative frequency pairs), and 16 DVS levels which is shown in Table 1.

T= $\{T_1, T_2 \dots T_n\}$ represents a set of independent tasks, where T_j is the jth task, W= $\{w_j, 1<j<n\}$ represents set of task computational workload and EXT= EXT [i, j] m×n is the matrix of task execution times in each resource. EXT [i, j] denotes an expected time for the execution of task T_i on resource R_j.

C. Energy Consumption

According to task computational workload and resource computing capacity, the execution time needed for executing task T_i on resource R_j defined as:

$$EXT\,[i, j] = W\,(t_i)/rcc\,(r_j) \tag{6}$$

Supply power and frequency decrease while tasks execution time increase, when task T_i execute on resource R_j at DVS level si, EXT matrix can be defined as follows:

$$EXT'[i,j] = [\frac{1}{fs1(i)}.EXT[i,j], \frac{1}{fs2(i)}.EXT[i,j], \dots, \frac{1}{fs1\ max(i)}.EXT[i,j] \tag{7}$$

Where EXT [i, j] can be calculated according to the Equation (7), $\{fs_1(i), fs_2(i), \dots, fs_l(max)(i)\}$ denotes the relative frequency insufficient, specified for strategy si at $\{s_1,s_2,\dots,s_l(max)\}$ DVS levels. The energy consumption model is derived from the power consumption module in complementary metal-oxide-semiconductor (CMOS) logic circuits. The power consumption of the CMOS-based processor defined to be the summation of capacitive, short-circuit and leakage power. The capacitive power (dynamic power consumption) is the most significant factor of the power consumption [13]. It can be calculated in the following way:

$$P=A.C.V^2.F \tag{8}$$

Where A is the number of switches per clock cycle, C is the total capacitance load, v is the supply voltage, and f is the frequency. The energy consumed by resource R_j for the execution task Ti at DVS level sl can be defined as follows:

$$E[i,j]=Y\times[(vs_1)(i)]^2\times[(fs_1)(j)]\times f\times EXT'[i,j,s_1] \tag{9}$$

Where Y=A*C assumed constant for a given resource, $vs_l(i)$ is a voltage supply value for strategy s_i, R_i at DVS level sl for computing task t_i, $fs_l(j)$ is the relative frequency, and ETC' [i, j, sl] is the lth coordinate of ETC' [i, j] vector.

$$Ei=\sum_{i\in L(j)}^{j\in T(i)}\{Eijl\} + \Upsilon\,[vs_{min}\,(i)]^2.\,[fs_{min}\,(i)].f.\,Idle\,(i)$$
$$= \Upsilon.f.\{\sum_{i\in L(j)}^{j\in T(i)}[vs_{min}\,(i)]^2.[fs_{min}(i)]\,.\,f\,.\,Idle\,(i) \tag{10}$$

Where T (i) is the set of tasks assigned to resource R_j, L (j) is the set of DVS level used for these tasks on resource R_i, vs_{min} (i), fs_{min} (i) represents the minimum supply voltage and relative frequency in the idle time that resource turn into sleep mode and Idle (i) is an idle time of resource R_i. The idle time for resource R_i can be calculated in following way:

$$Idle\ i= Makespan - completion\ (i) \tag{11}$$

For the resource with makespan, the idle time is equal to zero. So total energy consumption is as follows [4]:

$$E\_{total}=\sum_{i\in m} Ei \tag{12}$$

TABLE I. DVS Levels And Pairs

	Pair 1		Pair 2		Pair3	
Level	**Vol (Vs1)**	**Rel.f (fs1)**	**Vol (Vs1)**	**Rel.f (fs1)**	**Vol (Vs1)**	**Rel.f (fs1)**
0	1.5	1.0	2.2	1.0	1.75	1.0
1	1.4	0.9	1.9	0.85	1.4	0.8
2	1.3	0.8	1.6	0.65	1.2	0.6
3	1.2	0.7	1.3	0.50	0.9	0.4
4	1.1	0.6	1.0	0.35		
5	1.0	0.5				

D. Makespan

In this paper the scheduling aim is to minimize makespan and total energy consumption. Generally, there are two solutions:

1) Scheduling aims to find the smallest energy consumption when execution time is limited. That is E_opt=min(E_total),while makespan_opt<=makespan_expected.

Where E_opt is the minimum energy consumption, makespan_opt is the minimum makespan that can have.

*Corresponding author

2) Scheduling aims to find the smallest energy consumption when the cumulative energy consumption limited, that is makespan_opt=min (makespan), while E_opt <= E_expected. Makespan can be described as follows:

$$\text{Minimize } f_{(cs)} = F_{max}(s) \tag{13}$$

Where $f_{(cs)}$ is a candidate solution and F define the completion time of task T_i on resource R_j. For example, the scheduler has eight independent tasks scheduled on two resources and the sequence of tasks is T_6-T_5-T_2-T_1-T_7-T_4-T_3-T_0, Fig. 1 explains calculation method of makespan:

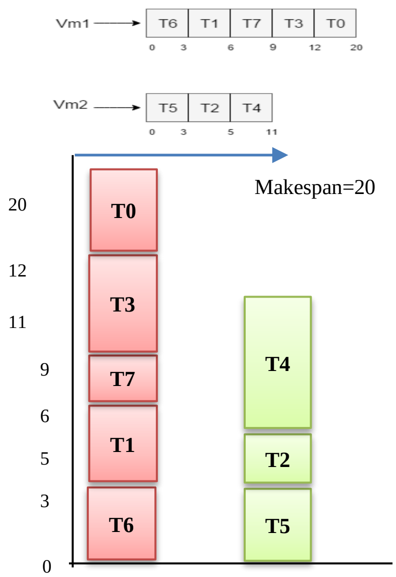

Fig. 1. Makespan definition.

We consider the scheduling as a bi-objective problem which aiming to find the right compromise between makespan and E_total.

The obtained results of the considered functions have not same unit. For this purpose, we use normalization. The used normalization formula is as follows:

$$\text{Normalization}(Q_c)=\begin{cases} \dfrac{Q_c\text{-}Q_i(\max)}{Q_i(\max)\text{-}Qi(\min)} & Q_i(\max)\neq Q_i(\min) \\ 1 & \& Q_i(\max)=Q_i(\min) \end{cases} \tag{14}$$

Where Q_c is the obtained result, Q_i (max) is the maximum obtainable value, and Q_i (min) is the minimum value can be obtained. We are used minimum makespan and minimum energy consumption equal to zero and maximum makespan and energy consumption obtained by sends all the tasks to the weakest resource. There are two parameters in the total fitness function, any changes in the parameters show the user's demands from the scheduler. In other words, these two parameters used as coefficients. The sum of the parameters should be equal to one so the fitness function of the bi-objective scheduling is as follows:

$$(\theta 1)\times(\text{normal-makespan})+(\theta 2)\times(\text{normal} - \text{energy}) \tag{15}$$

*Corresponding author

Table 2 shows the examples of possible states:

TABLE II. FITNESS FUNCTION PARAMETERS

θ1	θ2	Makespan	Energy
0	1		✓
1	0	✓	
0.5	0.5	✓	✓

V. PROPOSED ALGORITHM

A. Chaotic Bat Algorithm

We describe a chaotic heuristic algorithm to send tasks to the makespan and energy aware resources, and we call it bi-objective chaotic bat Algorithm for task scheduling. CBA use the execution time, the execution energy to improve the task scheduling. All bats have properties that explained in related works (Bat algorithm) in five sections. The initial population mainly aims to find the food/prey and a faster convergence, as well as improvement in the best global solution. Each bat has some other parameters as follows:

α: is a loudness decay factor. It is also used as a cooling factor in the traditional simulated annealing algorithm.

γ: is the pulse enhancement factor that used for adjustment of the pulse frequency.

r_i: which makes the local search is done further and with more accuracy.

Ai: is loudness, which makes the algorithm explore the search space globally.

In this section, we are used chaotic maps in different ways to tune the BA parameters and improve the performance. In chaotic sequences, the numbers are well distributed. Iterative map and sinusoidal map has had good performance in the initialization process. This specification can be effective in an evolutionary algorithm. This feature can get a better exploration in the evolutionary algorithm. So, for each bat, we used the sinusoidal map to initialize pulse emission rate and the iterative map for loudness frequency initialization[6]. Descriptions of the two maps are as follows:

Iterative map: The iterative chaotic map with infinite collapses can be written as [6].

$$X_{k+1=\mathrm{Sin}}\left(\frac{\alpha\pi}{xk}\right) \tag{16}$$

Sinusoidal map**:** we can define Sinusoidal map by the following equation:

$$X_{k+1}=\alpha xk^2 \sin(\pi xk) \tag{17}$$

Tasks randomly distributed between resources. If we consider 'n' as an initial population, so we have 'n' solutions (bats).We used the chaotic value distributions of 100 iterations for two maps with random initial values.

VI. SIMULATION AND RESULTS

Simulations were carried out to compare the optimization ability of the proposed algorithm (CBA) [14] in scheduling problem with the classical BA [5], GA [4], PSO with dynamic inertia weight [15], [16] and Symbiotic organism [2]. We use chaotic maps for Performance improvements. The simulation carried out using Matlab (R2014a) and Table 3 shows parameter settings of the algorithms for task scheduling. We are considered the maximum algorithm iterations equal to 500, and in energy consumption and total fitness function we are used 1500 iteration to obtain convergence which is also considered as a condition for termination, and a fixed population n = 100 is used for all simulations.

TABLE III. ALGORITHMS PARAMETERS

BA	[r=random initialize] [fmin=0,fmax=number of resource] [**α= 0.9**] [**γ=0.9**] [A= random initialize]
CBA	[r= initialize using Sinusoidal map][fmin=0,fmax=number of resource][**α=0.9**][**γ=0.9**] [A=initialize using Iterative map]
PSO	[w=0.4-0.9] [c1,c2=2]
GA	[cross over rate=0.9] [mutation rate=0.01]
DSOS	[number of organism=100]

Web applications such as web services are usually run for a long time and their CPU requests are variable. Moreover, High-Performance Computing (HPC) applications have short life span and place a high demand on CPU. Furthermore, chosen statistical models for task sizes represents different scenarios of concurrently scheduling HPC and web applications. Uniform distribution depicts tasks where HPC and web applications have the same value. The left-skewed distribution represents a state where HPC applications to be scheduled more than web applications and right skewed distribution represents the Reverse this state. The normal distribution represents a tasks where a single type of application is scheduled. To test the ability of the algorithms, we randomly generated five types of scenarios (tasks) which shown in Table 4. We use 15 resources and random numbers (1000 to 10000) for processing capacity of each resource (million instructions per second) and a number of machine instructions for each task generated using normal, uniform, right-skewed and left skewed distribution. The normal distribution contains more medium size tasks and fewer small and large size tasks. Left-skewed represents a few small size tasks and rather a large size tasks while right skewed is the opposite. Uniform distribution depicts an equal number of large, medium, and small size tasks. For each distribution, 20, 30, 50, 100, 200, 300 tasks were generated which they have been named as scenarios.

TABLE IV. SCENARIOS

Scenarios	**Number of tasks**	**Number of resources**
Scenario1	20	15
Scenario2	50	15
Scenario3	100	15
Scenario4	200	15
Scenario5	300	15

*Corresponding author

A. Scheduling Scenarios by Considering Makespan

The following experiments and analysis are based on the makespan including CBA, BA, GA, DSOS and PSO algorithm with dynamic inertia weight for normal, uniform, right and left skewed generated tasks.

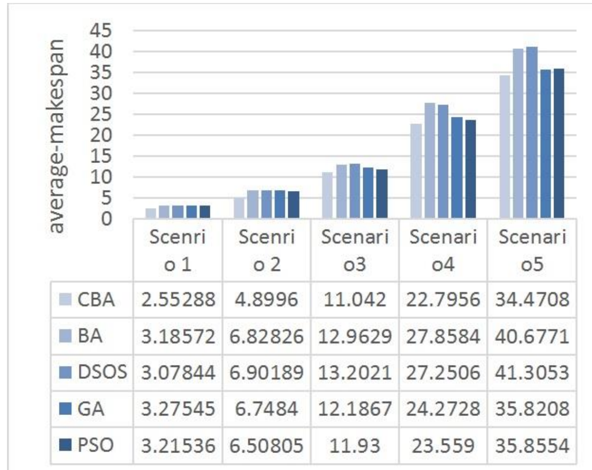

Fig. 2. Average of makespan in 10 repetition (normal).

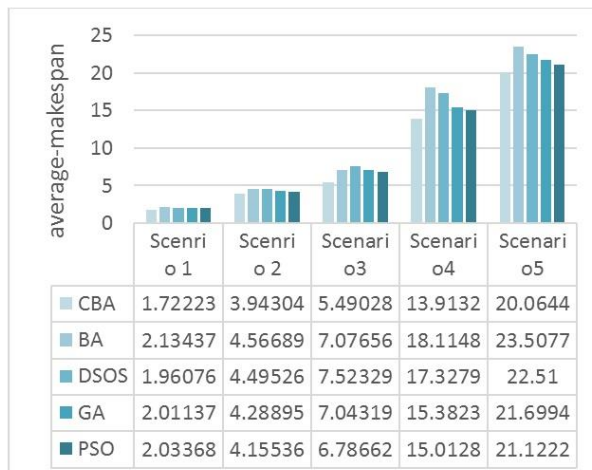

Fig. 3. Average of makespan in 10 repetition (uniform).

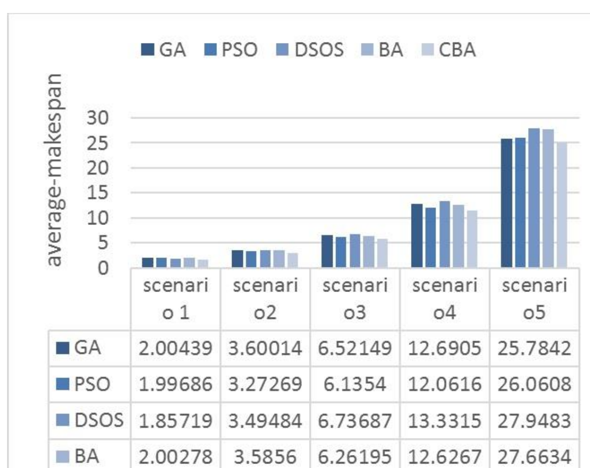

Fig. 4. Average of makespan in 10 repetition (Right-Skewed).

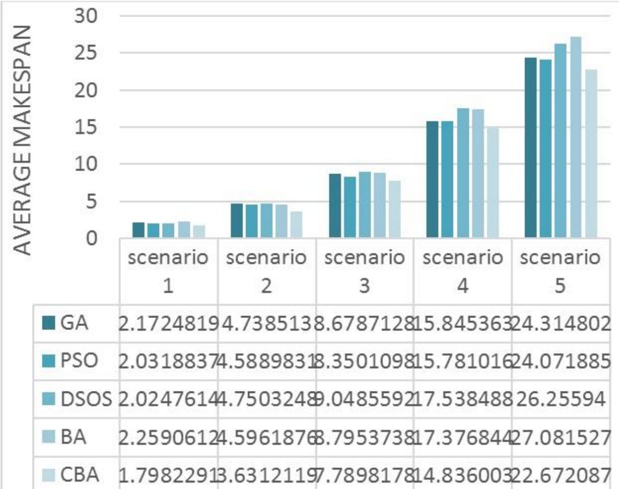

Fig. 5. Average makespan in 10 repetition (left skewed).

B. *Scheduling Scenarios by Considering Energy Consumption*

In this section, we test GA [4] and proposed algorithm by considering the energy consumption in four different distributions tasks.

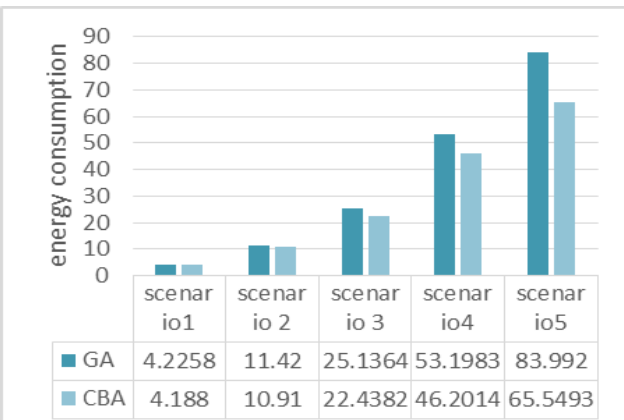

Fig. 6. Average energy in 10 repetition (normal).

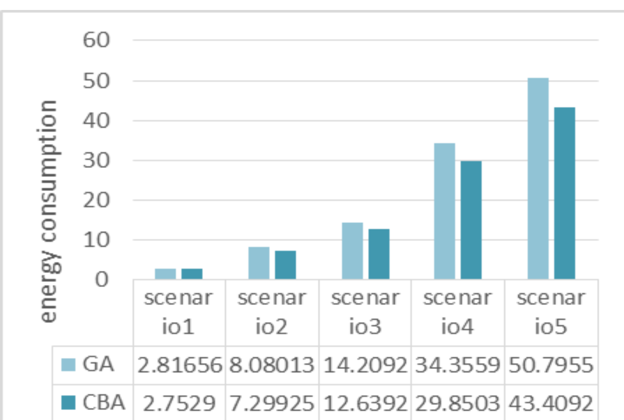

Fig. 7. Average energy in 10 repetition (uniform).

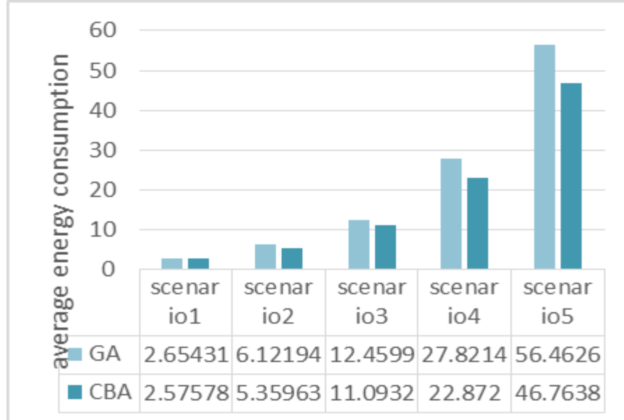

Fig. 8. An example of convergency (right-skewed).

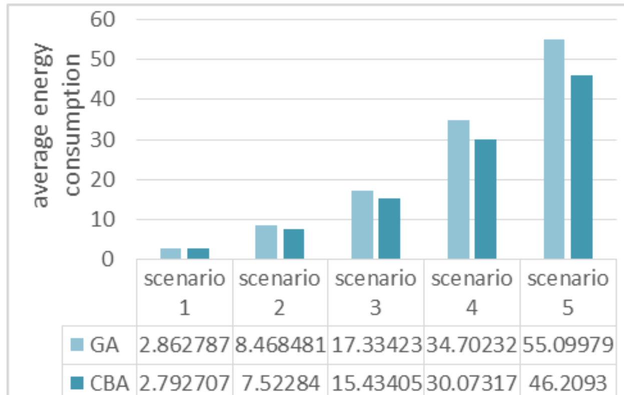

Fig. 9. Average energy in 10 repetition (left-skewed).

C. *Scheduling Scenarios by Considering Total Fitness*

In this section, experimental results show the Bi-Objective results of running each algorithm. In this results, θ value is equal to 0.5. Results shows that, by increasing the number tasks amount of energy consumption and makespan increases and proposed algorithm can obtain the better result than other algorithms.

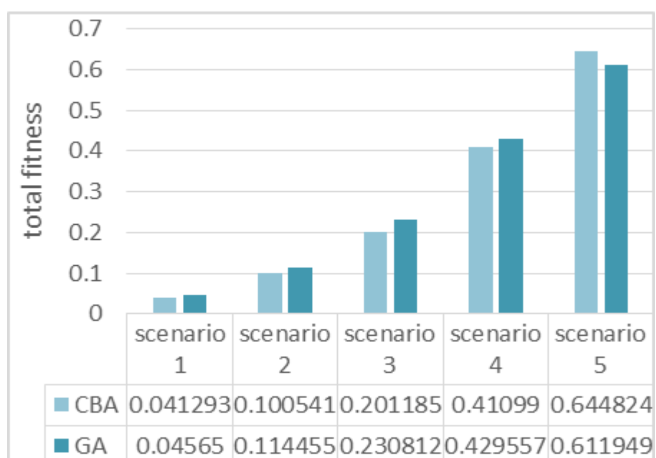

Fig. 10. Average total fitness in 10 repetition (normal).

*Corresponding author

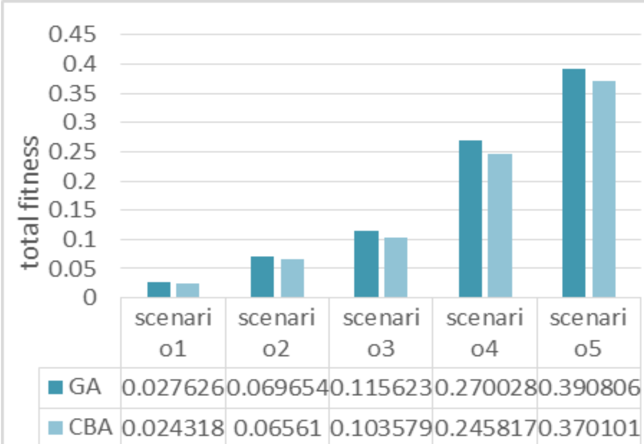

Fig. 11. Average total fitness in 10 repetition (uniform).

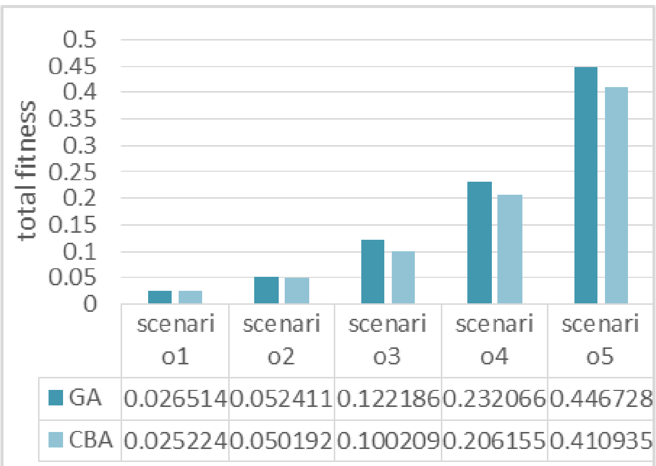

Fig. 12. Average total fitness in 10 repetition (right-skewed).

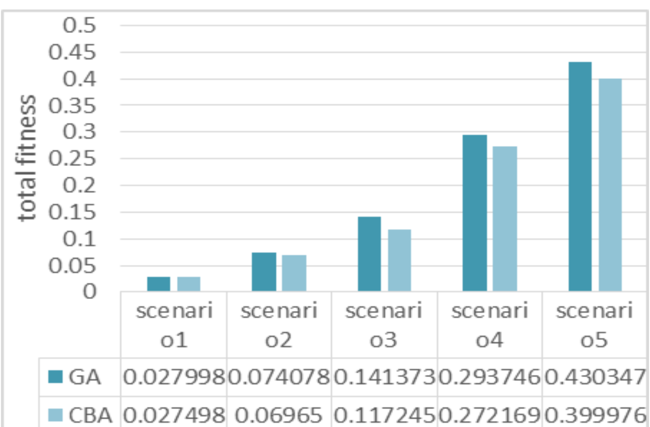

Fig. 13. Average total fitness in 10 repetition (left-skewed).

In Section VI-A, Fig. 2 to 5 show the average makespan of each algorithm by run 10 times in 5 scenarios with 5 type of tasks. It shows that the makespan will increase when the number of tasks increased. Also according to these figures, the proposed algorithm has achieved lower makespan than the other algorithms. It is noteworthy that when the number of incoming tasks are increased proposed algorithm has gained better results than GA but when the number of tasks is much, sometimes the CBA converged later than GA but obtained results are better than it. In section B As indicated, energy consumption is considered. Fig. 6 to 9 show the average energy consumption of each algorithm by run 10 times in 5 scenarios with 5 type of tasks. In the last part (total fitness), Fig. 10 to 13 represent obtained results by considering the energy consumption and makespan. Results shows the sum of the normalized energy consumption and makespan multiplied by Theta coefficient. It is obvious the proposed algorithm can obtain better total fitness than another algorithm. It is noteworthy that in some scenarios, especially when the number of tasks is less both algorithm results are very near but with the increasing number of tasks proposed algorithm has overtaken from genetic algorithm.

VII. Conclusion and Feature Scope

We have studied scheduling problem in cloud computing environments. This paper explained an advanced task scheduling algorithm based on chaos and the effect of using chaotic sequences for improvement of results. In this paper, the chaos maps have used to improve the performance of Bat Algorithm, as well as the global search by using a good distribution of numbers in order to escape the local optimum. The use of chaos is one of the techniques to tune some of the parameters in algorithms. In the recent optimization literature, chaos has become an active research topic and researchers paid special attention to it. By comparing obtained results by Chaotic Bat Algorithm and other algorithms, the results showed that the improvement of the makespan and energy consumption, due to use of deterministic chaotic signals in part of constant parameters. Experimental results of the CBA proposed that the tuned algorithms can clearly improve the reliability and the convergence of the global optimality, and they also enhanced the quality of the results. When we use a CBA, running time of chaos maps leads to increase the total running time of the algorithm However, this time is minimal. Second, the algorithm late converged by taking energy Criterion when the number of tasks was much. An interesting question arises how some chaotic maps can improve the performance of an algorithm, while others do not. It is still not clear why the use of chaos in an algorithm to replace some parameters can change the performance. Experimental results show that the proposed algorithm in this problem is superior to other heuristics algorithms.

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*Corresponding author

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*Corresponding author

Tagging Urdu Sentences from English POS Taggers

Adnan Naseem
Department of Computer Science
COMSATS Institute of Information Technology,
Islamabad, Pakistan

Salman Ahmed
Department of Computer Science
International Islamic University,
Islamabad, Pakistan

Faizan Rasul Hashmi
Department of Computer Science
University of Lahore,
Lahore, Pakistan

Muazzama Anwar
Department of Computer Science
COMSATS Institute of Information Technology,
Islamabad, Pakistan

Qadeem Akhtar Satti
Department of Computer Science
COMSATS Institute of Information Technology,
Islamabad, Pakistan

Tahira Malik
Department of Computer Science
University of Lahore,
Lahore, Pakistan

***Abstract*—Being a global language, English has attracted a majority of researchers and academia to work on several Natural Language Processing (NLP) applications. The rest of the languages are not focused as much as English. Part-of-speech (POS) Tagging is a necessary component for several NLP applications. An accurate POS Tagger for a particular language is not easy to construct due to the diversity of that language. The global language English, POS Taggers are more focused and widely used by the researchers and academia for NLP processing. In this paper, an idea of reusing English POS Taggers for tagging non-English sentences is proposed. On exemplary basis, Urdu sentences are processed to tagged from 11 famous English POS Taggers. State-of-the-art English POS Taggers were explored from the literature, however, 11 famous POS Taggers were being input to Urdu sentences for tagging. A famous Google translator is used to translate the sentences across the languages. Data from twitter.com is extracted for evaluation perspective. Confusion matrix with kappa statistic is used to measure the accuracy of actual Vs predicted tagging. The two best English POS Taggers which tagged Urdu sentences were Stanford POS Tagger and MBSP POS Tagger with an accuracy of 96.4% and 95.7%, respectively. The system can be generalized for multi-lingual sentence tagging.**

***Keywords*—Standford part-of-speech (POS) tagger; Google translator; Urdu POS tagging; kappa statistic**

I. Introduction

One of the most fundamental parts of the linguistic pipeline is part-of-speech (POS) tagging. POS tagging is the process of assigning grammatical tags (nouns, verbs, adjectives, adverbs) to each word in a text. This is a basic form of syntactic analysis of the language which has many applications in NLP. Most POS taggers are trained from treebanks in the Newswire domain, such as the Wall Street Journal corpus of the Penn Treebank. However, Stanford POS Tagger is widely used by the researchers due to its multi-lingual (computer language) support packages. Such as, Docker, F#/C#/.NET, GATE, Go, Javascript (node.js), PHP, Python, Ruby, XML-RPC and Matlab. Therefore, Stanford POS Tagger is considered as an example in this paper. Output from the rest of the POS Taggers is not discussed due to the page limitations. Challenges encountered due to the termination of tagging out of domain data, and nature of Twitter text conversations, lack of traditional orthography, and 140-character length limit for each message ("Tweet").

Since, the Internet has become a major medium of social interaction and communication. Whereas, the medium of communication is English, therefore, a rich source of information pool is growing with a very fast pace comprising some useful information. However, it is a tight and hard practice to filter out the useful information from such a massive stuff. Majority of contribution regarding to developing tools took place regarding to the English based communication. In case of POS tagging a rich literature is available regarding to English POS Taggers as compared to other languages. Each POS Tagger is working decently inside its domain and within its limitations. A lot of researchers natively other than English, are also contributing in English literature. However, the valuable information other than in English language is also as important as others. Apart to bring a decent amount of researchers to take part in non-English text, an idea of reusing English tools, techniques, methodology is proposed. More specifically, English POS taggers are to be reused for tagging non English language text.

In this research, after an extensive literature review of English POS Taggers, the Stanford POS Tagger, written specifically for English sentences is reused to tag Urdu sentences as an example. Twitter API is used to extract the Urdu sentences (tweets) on a specific topic from the Twitter. After the refinement process, sample of Urdu sentences is randomly selected for further processing. Google Translator is used to translate the sampled Urdu sentences into English, for tagging from Stanford POS Taggers. The state-of-the-art English POS Taggers were extracted and included in this exercise. However, their detailed result will be included in the extended version of this study. Such English sentences were injected into the Stanford POS Tagger to yield tagged-English sentences. These tagged-English sentences are translated back to their original language with the help of Google translator. Two human annotators tagged the original sample of Urdu sentences as benchmark tagged sentences. *Kappa statistic* along with confusion matrix is applied to measure the accuracy of each tagger for Urdu tagging.

The rest of the paper is structured as follows: Section II comprises extensive background knowledge. Section III discusses the methodology of the research. Results and Future Implications are discussed in Section IV. Conclusion, limitations and future work are placed as final sections.

II. Background Knowledge

In this section, an extensive background knowledge is presented as shown in Tables 1(a) and (b). A decent amount of literature has been carried out till date, however, current research is different in case of re-usability of benchmark POS Taggers, and generalizability of the idea. Additionally, State-of-the-Art English POS Taggers are also the part of this section.

TABLE I. (a). Background Knowledge

Sr. No	POS Tagger Name	Technique	Result	References
1	CLE Urdu Parts of Speech	CLE Urdu Digest Tagged Corpus	96.8	[1]
2	N-gram based part of speech tagger for the Urdu language	N-gram Markov Model	95.0	[2]
3	Improving part-of-speech (POS) tagging for Urdu	Humayoun's morphological analyzer, SVM Tool tagger trained	87.98	[3]
4	Solve the parts of speech tagging problem of urdu language	Hidden Markov Model		[4]
5	Four state-of-art probabilistic taggers	Tnt tagger, treetagger, RF tagger and SVM tool	95.66% by SVM tool	[5]
6	First computational part of speech tagset for Urdu	Creating one of the necessary resources for the development of a POS tagging system for Urdu		[6]
7	A rule-based methodology is used here to perform tagging in Urdu	Unitag architecture		[7]
8	NER systems for the Urdu, Hindi, Bengali, Telugu, and Oriya languages	Language specific rules and Maximum Entropy (ME)	Hindi, Bengali, Oriya, Telugu, and Urdu NER systems in terms of fmeasure were 65.13%, 65.96%, 44.65%, 18.74%, and 35.47% respectively	[8]
9	A design schema and details of a new Urdu POS tagset	The Penn Treebank	Accuracy of 96.8%.	[9]
10	Named Entity Recognition (NER) system for Urdu language	Urdu NER system		[10]
11	Named Entity Recognition	Rule-based Urdu NER algorithm		[11]
12	Problems of NER in the context of Urdu Language	IJCNLP-08 and Izaafats	Twelve NE proposed	[12]
13	NER on Conditional Random Field (CRF)	Precision, recall, and f-measure	63.72%, 62.30%, and 63.00% as values for precision, recall, and fmeasure	[13]
14	Developing a wordnet for Urdu on the basis of Hindi wordnet.	Wordnet		[14]
15	To develop models which map textual input onto phonetic content	Thus Urdu pronunciation may be modelled from Urdu text by defining fairly regular rules	Takes textual input and converts it into an annotated phonetic string.	[15]
16	With developing a lexical knowledge resource for Urdu on the basis of Hindi wordnet	Transliterators	Computational semantics based on the Urdu pargram grammar	[16]
17	UZT 1.01 standard	Unicode		[17]
18	Vowel insertion grammar for Urdu language	Building speech synthesis for Urdu language		[18]
19	Of automated Part-of-speech tagging	Maximum Entropy (ME) modelling system , Morphological analyser(MA) and stemmer	Proposed different models ME, ME+Suf, ME+MA, ME+Suf+MA	[19]
20	Release of a sizeable monolingual Urdu corpus automatically tagged with part-of-speech tags	Monolingual corpus and release the tagged corpus	88.74%	[20]
21	Analyzing the political News Corpus for finding Important Entities,	Heuristic based Salience Analysis of Urdu News Corpus	85.5	[21]

	Saliences in the Urdu language			
22	Efficient methods of computational linguistics.	Tnt tagger, Maximum Entropy tagger and CRF (Conditional Random Field)	.tnt tagger manages to obtain 93.56 for Urdu	[22]
23	Urdu-to-English transliteration	Bootstrap	84.1%	[23]
24	Evaluation of URDU.KON-TB in the dependency parsing domain.	Maltparser, The algorithm used to train and test data is Nivre arc-agear algorithm.	The experiments results show URDU.KON-TB treebank is not suitable for the dependency parsing as dependency relation because Head information was missing in the treebank.	[24]
25	Statistical model used in this work is HMM along with IOB chunk annotation	Tnt Tagger	97.52%	[25]
26	Noun phrase chunker for Urdu which is based on a statistical approach	HMM based approach	97.61	[26]

TABLE I. (b). STATE OF THE ART ENGLISH POS TAGGERS

Sr. No	Name of POS Tagger	Available online?	Supported Programming Languages	Results
1	CRF tagger	No	Java	97.00%
2	Citar - Trigram HMM part-of-speech tagger	No	C++ version available	
3	JsPOS	No	Javascript	
4	Term Extractor	No	Python package	
5	Stanford Log-linear Part-Of-Speech Tagger	No	Multiple language bindings	
6	MorphAdorner	Yes	Generic	96-97%
7	spaCy	Yes	Python/Cython	
8	SMILE Text analyzer	Yes	Java API	
9	LingPipe	No	multiple	
10	Apache OpenNLP	No	Java	
11	RDRPOSTagger	No	Python	
12	Brill's Tagger	Yes		95-97%
13	TnT	No	Multiple	95.99%
14	HunPOS	No	Multiple	95.97%
15	dTagger	No		95.1%
16	MaxEnt	No	Python, java	97.23%
17	Curran & Clark	No		97%
18	Tree Tagger	Yes	multiple	
19	Rosette based linguistic	No	Commercial Product	
20	Memory based tagger	Yes	TiMBL, C++	
21	SVM Tool	Yes but not working	SVM based	97.2%
22	ACOPOS tagger	No	C	
23	MXPOS tagger	No	Java	
24	fnTBL	No	C++ transformation based	
25	GPOSTTL	No	PHP+mysql enhanced version of brill's tagger	
26	muTBL	No	Transformation based learner	
27	YamCha	No	SVM based C/C++ open source	
28	QTag	No	HMM Java based	
29	Lingua-EN-Tagger	No	Perl	
30	CLAWS	Yes		96-97%
31	Infogistics	Yes		96-98% for known words and 88-92% for unknown words
32	AMALGAM tagger	No		
33	TATOO	No	Perl	

III. Research Methodology

This section comprises the methodology of the current research. Twitter APIs are used to extract the data on a specific topic. Data from Twitter for a novice topic PANAMA CASE is extracted with the help of Twitter API. Raw data are refined and ten sample sentences are randomly picked for further processing. Google Translator was used to translate the sampled Urdu sentences into English, for tagging from famous English POS Taggers, which were extensively explored from the literature. Such English sentences were injected into each tagger to yield tagged-English sentences. These tagged-English sentences were translated back to their original language with the help of Google translator. Two human annotators tagged the original sample of Urdu sentences as benchmark tagged sentences. *Kappa statistic* along with confusion matrix was applied to measure the accuracy of each tagger for Urdu tagging. Best two POS Tagger for Urdu sentences is hence prioritized. The whole process from step, selecting sample to find the accuracy was repeated three times to get the best results. On exemplary basis only Stanford POS Tagger is considered at this stage. The reason behind the consideration of Stanford POS Tagger here is, it outperformed the rest of the POS Taggers with 96.4% kappa statistics. The detailed results of the rest of the POS Taggers can be provided on demand. Below is the research methodology of current study in Fig. 1.

Twitter[1] is a social networking platform where millions of users communicate each day, billions of short text messages (up to 140 characters) tweets. Tweets on specific political issues were used to get tweets related to the keyword (Panama, PMLN and TTP). However, we make sure filter the unique tweets written in Urdu while we review the mesh by Twitter API[2]. To avoid re-tweets, the same check in the API is placed. The Hash functions were used to eliminate duplicate tweets. All non-Urdu characters were filtered out at the very first stage of the refinement, i.e. URLs, twitter connector (@username) and hashtags (#PTI, #PMLN) from tweets and then put them as a key in HashMap. Original tweets were used as the value of these keys. After running this procedure on all tweets, the number of tweets was reduced by approximately 40%. This remaining tweets can be safely said as unique tweets. Every Tweet was treated as a new sentence.

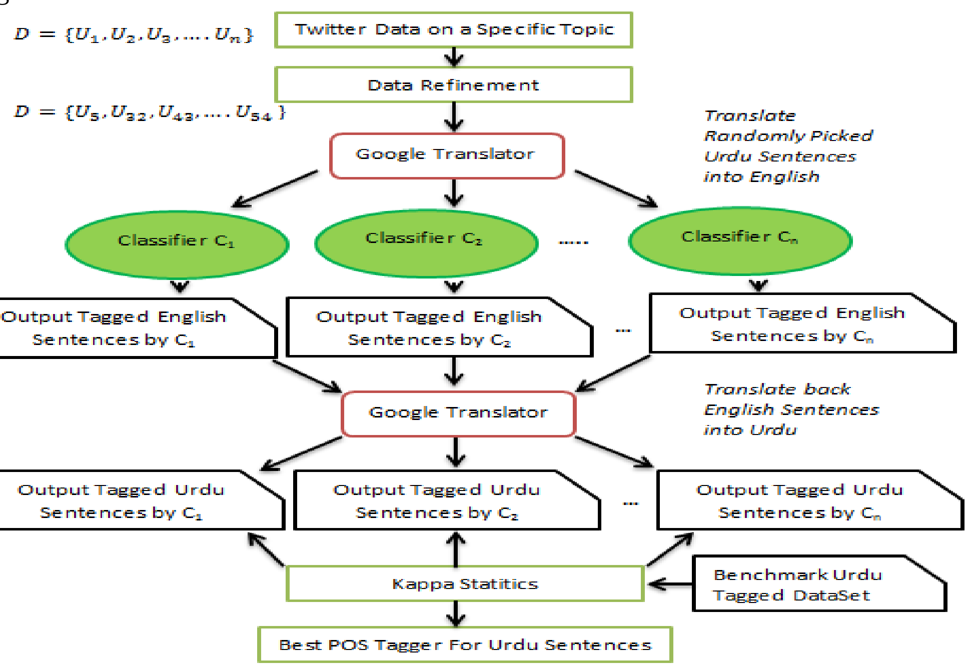

Fig. 1. Research methodology.

A random sample of 10 sentences/tweets was considered for further processing as shown in Table 2. A decent amount of literature claims different types of English POS Taggers. However, Stanford POS Tagger was used at this stage for further processing. Yet, all other state-of-the-art famous POS Taggers will be discussed extended version of current study. Moreover, these taggers can be re-useable to tag multi-lingual sentences. Additionally, the overall result of all POS Taggers is provided in Fig. 2. In order to translate sampled Urdu sentences into English sentences, an Urdu-to-English translator namely, Google Translator[3] was used.

These translated English sentences were injected into a Stanford POS tagger. The output of this step was tagged translated English sentences as resulted in Table 3.

Google translator was used again to translate back the Tagged translated English sentences into the original form, i.e. Urdu as shown in Table 4.

[1]http://twitter.com/
[2]http://twitter4j.org/en/index.html
[3]https://translate.google.com/

TABLE II. SAMPLE TWITTER SENTENCES

Sampled Urdu sentences From Twitter	S. No.
عائشہ گلالئی نے قیادت پر الزام لگایا، ضرور کچھ ہوا ہوگا۔	.(1
عوام نے پانام کیس کا فیصلہ تسلیم نہیں کیا۔	.(2
الحمد للہ آج ریلی میں 1 کروڑ لوگ شریک ہوئے۔ دیکھ سکتے ہو تو دیکھ لو۔	.(3
نوازشریف پانامہ کیس فیصلے کے بعد عوام کو گمراہ کرنے کی کوشش کررہے ہیں۔	.(4
پاناما کیس میں نااہلی کے بعد نوازشریف کا لاہور کا پہلا سفر۔	.(5
بچے کی ہلاکت پروالدین بے ہوش ہوگئے۔	.(6
نواز شریف کے قافلے میں بچہ جاں بحق۔	.(7
سابق وزیراعظم نواز شریف کا قافلہ گجرات شہرمیں داخل۔	.(8
کیپٹن ریٹائرڈ صفدر اور آصف کرمانی نے کلثوم نواز کے کاغذات نامزدگی جمع کروائے۔	.(9
آمریت کا دور اچھا ہوتا تھا سویلینز نے ملک تباہ کر دیا ہے،	.(10

TABLE III. SAMPLE TWITTER SENTENCES

<table>
<tr><th>Tagged English Sentences by Stanford POS Tagger</th><th>S.No</th></tr>
<tr><td>Aisha|NNP Gulalai|NNP blamed|VBD the|DT leadership|NN ,|, something|NN must|MD have|VB happened|VBN .|.</td><td>.(1</td></tr>
<tr><td>People|NNS has|VBZ not|RB recongnized|VBN panama|NN case|NN 's|POS decision|NN .|.</td><td>.(2</td></tr>
<tr><td>Today|NN ,|, there|EX are|VBP 1|CD million|CD people|NNS participating|VBG in|IN the|DT rally|NN .|. See|VB if|IN you|PRP can|MD see|VB .|.</td><td>.(3</td></tr>
<tr><td>Nawaz|NNP sharif|NN after|IN verdict|NN of|IN panama|NN case|NN is|VBZ trying|VBG to|TO mislead|VB people|NNS .|.</td><td>.(4</td></tr>
<tr><td>Nawaz|NNP Sharif|NNP 's|POS first|JJ visit|NN to|TO Lahore|NNP after|IN disqualification|NN in|IN the|DT Panama|NNP case|NN .|.</td><td>.(5</td></tr>
<tr><td>Parents|NNS became|VBD unconscious|JJ at|IN death|NN of|IN baby|NN .|.</td><td>.(6</td></tr>
<tr><td>Child|NN dies|VBZ in|IN carvan|NN of|IN nawaz|NN sharif|NN .|.</td><td>.(7</td></tr>
<tr><td>Former|JJ PM|NNP nawaz|NN sharif|NN 's|POS carvan|NN entered|VBD gujrat|JJ city|NN .|.</td><td>.(8</td></tr>
<tr><td>Captain|NN retired|VBD safdar|NN and|CC asif|NN kirmani|NNS submit|VBP nomination|NN papers|NNS of|IN kulsoom|NN nawaz|NN .|.</td><td>.(9</td></tr>
<tr><td>Dictatorship|NN was|VB good|JJ soviets|NN destroyed|VB country|NN .|PUNCT |X</td><td>.(10</td></tr>
</table>

TABLE IV. TAGGED URDU SENTENCES BY STANFORD POS TAGGER

<table>
<tr><th>Tagged Urdu Sentences by Stanford POS Tagger</th><th>S.No</th></tr>
<tr><td>عائشہ|NNP گلالئی نے|NNP قیادت|NN پر الزام لگایا|VBD ضرور، |MD کچھ|NN ہوا|VBN ہوگا|VB</td><td>.(1</td></tr>
<tr><td>عوام نے|NNS پاناما|NN کیس|NN کا|POS فیصلہ|NN تسلیم|VBN نہیں|RB کیا|VBZ</td><td>.(2</td></tr>
<tr><td>الحمد للہ آج|RB ریلی|NN 1 میں|CD کروڑ|CD لوگ|NNS شریک ہوئے|VBG دیکھ|VB سکتے|MD ہو تو|IN دیکھ لو|VB</td><td>.(3</td></tr>
<tr><td>نواز|JJ شریف|NN پانامہ|NN کیس|NN فیصلے|NN کے بعد|IN عوام|NNS کو گمراہ کرنے|VB کی کوشش کررہے|VBG ہیں|VBZ</td><td>.(4</td></tr>
<tr><td>پاناما|NNP کیس|NN میں|IN نااہلی|NN کے بعد|IN نواز|NNP شریف|NNP کا|POS لاہور|NNP کا پہلا|NN سفر|NN</td><td>.(5</td></tr>
<tr><td>بچے|NN کی|IN ہلاکت|NN پر|IN والدین|NNS بے ہوش|JJ ہوگئے|VBD</td><td>.(6</td></tr>
<tr><td>نواز|NN شریف|NN کے|IN قافلے|NN میں|IN بچہ|NNP جاں بحق|VBZ</td><td>.(7</td></tr>
<tr><td>سابق|NNP وزیراعظم|NNP نواز|NN شریف|NN کا|POS قافلہ|NN گجرات|VBG شہر|NN میں داخل|VBD</td><td>.(8</td></tr>
<tr><td>کیپٹن|NNP ریٹائرڈ|VBD صفدر|VBG اور|CC آصف|NN کرمانی|NNS نے کلثوم|NN نواز|NN کے|IN کاغذات|NNS نامزدگی|NN جمع کروائے|VB</td><td>.(9</td></tr>
<tr><td>| ڈیکٹیٹر شپ | NN | اچھا | JJ | سوویٹس | NN | کو تباہ کر دیا | VB | ملک | NN | | PUNCT | X |</td><td>.(10</td></tr>
</table>

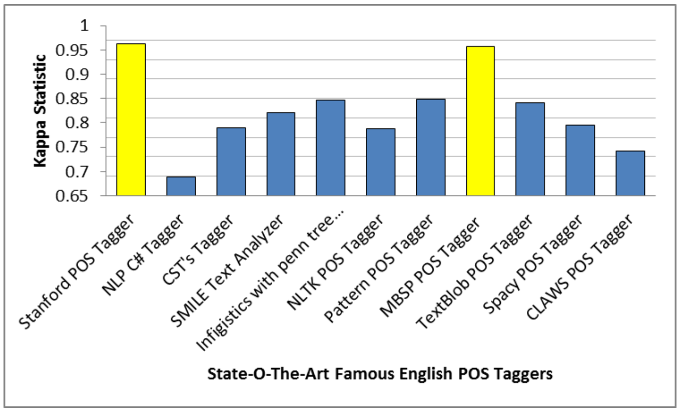

Fig. 2. Confusion matrix.

IV. Results and Future Implications

In order to check the accuracy of the subjected POS tagger with respect to Urdu language, Kappa Statistic with confusion matrix was considered. Manually annotations were applied with the help of two annotators to consider the best possible tags for original sampled Urdu data. Furthermore, Kappa Statistic with confusion matrix was applied to each tag used in Stanford POS Tagger for Urdu perspective as shown in Table 5. There were total 15 unique tags. The confusion matrix for actual tag (best possible) vs. predicted tag (tag assigned by Stanford POS Tagger) was synthesized for each of the following fifteen tags. Moreover, total accuracy and random accuracy were also calculated with the help of the following formula. Additionally, Kappa statistic was computed with the help of extracted values. The average value extracted by adding the individual kappa values of all the computed tags to the number of all tags. Accuracy of Urdu tagged sentences with the reuse of Stanford English POS Tagger was 96.4 on average, which is more than any of the existing Urdu POS Tagger. The process of randomly taking sample sentences was performed three times to remove the ambiguity of bias ness of sample selection.

Kappa Statistic

kappa= (Total accuracy - random accuracy)/ (1-random accuracy)

Total accuracy= (TP + TN)/ (TP + TN+ FP+FN)

Random Accuracy= (TN + FP)* (TN + FN) + (TP + FN)* (TP + FP)/ Total*Total

		Predicted Class	
		Not-NN	NN
Actual Class	Not-NN	TN	FN
	NN	FP	TP

Fig. 3. Confusion matrix.

In Fig. 3, TN is True Negative, FN is False Negative, FP is False Positive and TP is True Positive.

TABLE V. Kappa Statistic

			Predicted		**Total**	**Total accuracy**	**Random Accuracy**	**Kappa**	**Average Accuracy**
Tags			Not NN	NN					
		Not NN	52	0	83	0.975904	0.538104	0.947832	0.963088018
NN	**Actual**	NN	2	29					
NNP		Not NNP	74	0	83	1	0.806648	1	
	Actual	NNP	0	9					
VB		Not VB	79	0	83	1	0.90826	1	
	Actual	VB	0	4					
VBN		Not VBN	81	0	83	1	0.952969	1	
	Actual	VBN	0	2					
VBD		Not VBD	79	1	83	0.987952	0.919146	0.850987	
	Actual	VBD	0	3					
MD		Not MD	81	0	83	1	0.952969	1	
	Actual	MD	0	2					
VBG		Not VBG	81	0	83	1	0.952969	1	
	Actual	VBG	0	2					
CD		Not CD	81	0	83	1	0.952969	1	
	Actual	CD	0	2					
POS		Not POS	80	0	83	1	0.930324	1	
	Actual	POS	0	3					
NNS		Not NNS	77	0	83	1	0.865873	1	
	Actual	NNS	0	6					
RB		Not RB	82	0	83	1	0.976194	1	
	Actual	RB	0	1					
IN		Not IN	73	0	83	1	0.788068	1	
	Actual	IN	0	10					

VBZ		Not VBZ	80	0	83	1	0.930324	1	
	Actual	VBZ	0	3					
VBP		Not VBP	82	0	83	1	0.976194	1	
	Actual	VBP	0	1					
JJ		Not JJ	77	2	83	0.963415	0.896211	0.647501	
	Actual	JJ	1	2					

V. Conclusion, Limitations and Future Work

POS Tagging is considered to be an essential component of several NLP applications. The new POS Tagger is not easy to develop for unstructured data.Therefore, it affects the accuracy of tagging due to the diversity of the language. In this study, the idea of reusability of famous English POS taggers is used for tagging non-Engish sentences. A famous Google translator is used to translate the sentences across the languages. Data from twitter.com is extracted for evaluation perspective. Confusion matrix with kappa statistic is used to measure the accuracy of actual Vs predicted tagging. The result shows the accuracy of 96.4% for Stanford POS Tagger which is the best among 11 famous English POS Taggers. The system can be generalized for multi-lingual sentence tagging.

Alike other studies, current studies have also some limitations. Several translators have different translations of same sentence when translating the source language to target language. Additionally, even same translator translates a source language into targeted language, when re-translating the same text, produces different results. In this study, re-translation was carried out with the help of mapping the words. E.g. He is a boy. Wo aik larka ha. (he, wo), (aik, is), (larka, boy) and (ha, is). A customized Translator for specific language could ease the whole process. Another limitation of this study was the random selection of sentences. It was neutralized by taking the sample sentences thrice, however, the results were approximately same.

Short texts were used in this study; however, text other than from twitter will be used in an upcoming paper. Apart from the overall results, a detailed comparison of state-of-the-art English POS Taggers will be considered to rank the best POS Tagger for Urdu sentence tagging in the near future. Furthermore, sample data other than twitter will be considered for validation purposes. The current methodology could be used to tag multi-lingual tagging for the extraction of useful information. Therefore, a generic methodology for several different languages will be considered in future. Additionally, each language has different level of diversity; therefore, same methodology could be applied to several languages to avoid the development of novice complex taggers.

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Energy-Aware Virtual Network Embedding Approach for Distributed Cloud

Amal S. Alzahrani
Collage of Computer Engineering and Science
Prince Sattam Bin Abdulaziz university
Riyadh, Kingdom of Saudi Arabia

Ashraf A. Shahin[1,2]
[1]College of Computer and Information Sciences,
Al Imam Mohammad Ibn Saud Islamic University (IMSIU)
Riyadh, Kingdom of Saudi Arabia
[2]Department of Computer, Institute of Statistical Studies & Research, Cairo University, Cairo, Egypt

***Abstract*—Network virtualization has caught the attention of many researchers in recent years. It facilitates the process of creating several virtual networks over a single physical network. Despite this advantage, however, network virtualization suffers from the problem of mapping virtual links and nodes to physical network in most efficient way. This problem is called virtual network embedding (“VNE”). Many researches have been proposed in an attempt to solve this problem, which have many optimization aspects, such as improving embedding strategies in a way that preserves energy, reducing embedding cost and increasing embedding revenue. Moreover, some researchers have extended their algorithms to be more compatible with the distributed clouds instead of a single infrastructure provider (“ISP”). This paper proposes energy aware particle swarm optimization algorithm for distributed clouds. This algorithm aims to partition each virtual network request (“VNR”) to sub-graphs, using the Heavy Clique Matching technique (“HCM”) to generate a coarsened graph. Each coarsened node in the coarsened graph is assigned to a suitable data center (“DC”). Inside each DC, a modified particle swarm optimization algorithm is initiated to find the near optimal solution for the VNE problem. The proposed algorithm was tested and evaluated against existing algorithms using extensive simulations, which shows that the proposed algorithm outperforms other algorithms.**

Keywords—Distributed virtual network embedding; energy consumption; particle swarm optimization; network virtualization; virtual network embedding; virtual network request; virtual network partitioning

I. Introduction

Cloud computing is a computational paradigm that deliver on demand, pay as you use services. These services include Software as a Service (SaaS) by allowing users to use application over internet, Platform as a Service (PaaS) as operating system, databases and web servers and Infrastructure as a Service (IaaS), such servers and software. In order to deliver these services, each cloud should encounter many resources, such servers to fulfill users’ demands, where each service will be dedicated to single user at time, thus increasing service cost and power consumption. On the other hand, failure in one server will have consequences on overall services provided.

One of the most important feature of cloud computing is virtualization. It is a method of logically partition physical resources in a way that one physical resource can accommodate multiple users’ demands at same time. As a result, sharing resources will help to reduce cost and energy consumption along with increasing resources utilization [1].

As part of virtualization, network virtualization caught attention of many researchers during the past few years. It facilitates the process of creating several virtual networks over a single physical network called Substrate Network “SN”. It provides resources sharing requirement over cloud computing infrastructure. Network Virtualization plays an important role as link between virtual and physical infrastructure. Therefore, the process of virtual resources allocation over the corresponding physical ones became a critical issue. This problem called Virtual Network Embedding “VNE”. It defined as the problem of mapping virtual nodes and links to physical nodes and paths [2].

The VNE problem can be divided into two stages: node mapping and link mapping. Node mapping is where each virtual node in the VN request should map to the corresponding one in the SN. The virtual node resource requirements never exceed what the physical node can offer. After this stage, link mapping takes place. Link mapping is more complicated than node mapping, the reason being that the virtual link should map to the physical path while keeping within the bandwidth (“BW”) constraints.

However, mapping virtual nodes and links in separate stages increases the embedding cost. This is because mapping two neighboring virtual nodes far away from each other increases the length of the substrate path.

The main concern regarding VNE problem is how to map virtual resource to physical one while maintaining lower embedding cost. Beside the importance of reducing the embedding cost, the energy consumption during mapping stage should be taken in consideration. Energy conservation means to utilize the SN resources in way that saves overall power. This can be done through switching off the underutilizing resources or migrating VN requests [3]-[6]. On the other hand, embedding VN requests over multiple domains had its fair share of attention [7], [8].

Embedding request can be solved in single ISP. In this situation it called intra-domain. In contrast, inter-domain mapping as in distributed clouds computing is considered a substantial topic in most of the recent researches conducted in the area of computer technology. It derives its importance from its ability to handle large amounts of requests due to the size of the resources offered. It is composed of multiple Datacenters ("DCs") distributed geographically [9].

Because of the distributed nature, important questions must be asked. Where is the best to place the VN requests? Which DC is the best to fulfill the virtual network's demands? How can virtual requests be placed so that cost and energy consumption constraints are maintained?

From these points, this paper proposed Energy Aware Virtual Network embedding based on particle swarm optimization algorithm. It intended to provide an optimization approach that aims to minimizing both embedding cost along with energy consumption in distributed clouds.

The proposed optimization approach is based on adopting Particle swarm optimization "PSO" algorithm in VNE problem. PSO is a population based algorithm that starts with candidate solutions in one iteration, and improve them in the next one [10]. The performance of the proposed algorithm was tested against existing algorithms. It presents noticeable improvements regarding energy consumption, revenue, acceptance ratio, VNE time, achieved and rejected resources comparing to some of the existing algorithms.

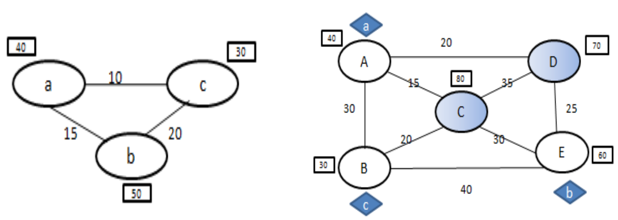
The rest of this paper is organized as follows. Sections 2 and 3 give a short overview of research background and related work. Section 4 presents the VN embedding model and problem formulation. Section 5 describes the proposed algorithm. Section 6 evaluates the proposed VN embedding algorithm. Finally, research conclusion is in Section 7.

II. Background

This paper is based on two technologies that form ground of the presented research, Network Virtualization and Particle Swarm Optimization.

A. Network Virtulization

Cloud computing can be defined as computing that delivers and permits access to shared resources over the Internet. Along with cloud computing, network virtualization considered a promising solution that accommodates the rapid growth of the Internet. It aims to support the creation of multiple virtual networks ("VNs") in the same shared physical network (Fig. 1).



a) VN request b) Substrate network

Fig. 1. Example of VN embedding.

A virtual network is composed of virtual nodes that are connected via virtual links. Network virtualization as an area is composed of two main players: Infrastructure providers (INPs), which are responsible for managing the physical infrastructure, and service providers (SPs), which are responsible for creating and maintaining VN requests [11]. However, despite this major flexibility that network virtualization brings, many questions have arisen regarding the problem of mapping the VN to the corresponding SN. This is called virtual network embedding and is defined as the problem of mapping virtual nodes and links to physical nodes and the corresponding path, respectively. It is considered an NP-hard problem [11].

Another problem that seems to have gained a lot of attention recently is energy consumption when mapping the VN. Many optimization solutions have been proposed over the last few years. These research projects aimed to solve the VNE problem with minimum embedding cost and better energy conserving strategies. Some of these proposed solutions followed the "Exact Solution" technique, where an optimal solution can be found through integer linear programming and mixed integer liner programming. However, such a technique is not Practicable in a large problem space. Therefore, heuristic and metaheuristic algorithms are presented as substitutes for traditional algorithms. These include genetic algorithms, simulated annealing, evolutionary programming and particle swarm optimization [2].

B. Particle Swarm Optimization

This paper focuses in modifying PSO algorithm to solve VNE problem to reach the goal of reducing embedding cost and energy consumption. This algorithm was inspired by birds' flock movements. Considering this algorithm as metaheuristic algorithm make it more applicable in large search space. PSO is optimization algorithm aims to find the near optimal solution among other candidate ones [10], [11]. In PSO, each candidate solution considered as particle, where each particle has its own position "x" and velocity "v". The optimization accomplished by moving each particle's position toward the optimal solution. This can be done by changing the particle's position and velocity according the following equation [18]:

$$v_i^d = wv_i^d + c_1 r_1^d \left(pBest_i^d - x_i^d\right) + c_2 r_2^d \left(gBest^d - x_i^d\right) \quad (1)$$

$$x_i^d = x_i^d + v_i^d \quad (2)$$

Where, $pBest_i^d$ is the particle's best position and $gBest^d$ is the best position in the whole swarm. Both r1 and r2 are random values and c1, c2 are cognition and social weight and w is inertia weight.

III. Related Works

As result to the importance of Network Virtualization, many researches were conducted to solve VNE problem [1] [12], [13]. In [12] Chevalier, C. and Safro, I. aimed to find near optimal solution for VNs embedding problems. First, they proposed a unified enhanced particle swarm optimization-based "VNE-UEPSO". The proposed algorithm focused on two stages: finding initial solutions "particles", and applying modified particle swarm optimization algorithm to find VNs embedding solution. Also, [6] presented embedding algorithm based on discrete particle swarm optimization. They modeled the VNE problem as binary optimization problem and proved by experiments that their algorithm consumes less computation time. In [14] author proposed a distributed algorithm for virtual networks mapping to substrate network resources. In addition, they proposed a VM mapping protocol to maintain communication and messages exchange between substrate nodes. The proposed algorithm has an impact on reducing the time delay in accepting multiple VN requests in same time. In [1], Kumar, R., and Charu, S. introduced a distributed protocol and VN embedding framework that ensure of mapping VN request across heterogeneous INPs. Additionally, they proposed “COST” addressing scheme for encoding and representing the geolocation information in each INP nodes. Another proposed protocol was Location Aware Protocol “LAP”. It worked as assistance protocol that helped Inps in making informed decisions regarding which INP should forward the VN request. In [15] authors aimed to provide solutions regarding the problems associated to the energy consumption in VN embedding. Their focus was on determine when and which virtual machine should be migrated, and to witch host. In [16] authors presented the algorithm to minimize the power consumption by switching off as many substrate nodes as possible without affecting the overall network performance. Additionally, they proposed Mixed Integer Program to solve VN embedding problem which considered as NP-complete. As in [17] the proposed work focused on two phases. Firstly, VM placement, that is achieved by Modified Best Fit Decreasing “MBFD”. This algorithm aimed to place VM with higher CPU utilization to a host that causes least power consumption. Second, VM selection which can be described as the process of choosing the VM that should be migrated to another host. From different point of view, [2] aimed to provide a solution for virtual network embedding in networked clouds. Their main contribution was mapping unbound virtual network request to different cloud sites. Their proposed solution consists of the following steps: 1) construct inter-domain physical graph; 2) construct cloud graph from the physical graph, where each node represents cloud site; 3) partitioned the virtual topology; and 4) find the solution with minimum embedding cost. In [3] authors proposed discovery framework for virtual resource organization across multiple infrastructure providers. The framework composed of two main parts: First, Management Nodes, “MN” responsible of maintaining and classifying the local virtual resource in each ISP to conceptual clusters. Each of these clusters named as Micro Cluster “MiC”. Second, the Cluster Index Servers, “CIS” is responsible of organizing each MiC with the same root to represent Macro Clusters, “MaC”. The proposed research’s main contribution was to find discovery framework that facilitates the organization of virtual resource across different Inp. In [18] authors proposed research aimed to solve both nodes and links mapping problem in intra-domain network. Researchers proposed algorithm worked in sorting the nodes according to their resource requirements. In contrast to previous works, they included link mapping cost in the sorting process. In [4], author proposed algorithms for assigning substrate network resources to virtual network components. They focused on node stress ration in the assignment process, where node with highest stress ratio is selected as center node. In [5], author presented algorithm that depend on additional factor while calculating the stress used for mapping VN in to heterogeneous SN. These additional parameters include: link bandwidth, CPU load and frequency, candidate nodes for each Virtual node and free RAM. In [7], author proposed two mapping algorithms: Integer Liner Programming and Heuristic algorithm. Their main goals were minimizing CPU, RAM load and Link load. On the other hand, the proposed heuristic algorithm was similar to the one discussed in [5] addition to some modifications. It included both CPU and RAM consumption in node stress calculations. Tuning value was added to reduce link-path cost and update link stress after each VN mapping.

IV. Virtual Network Embedding Model and Problem Formulation

In this section, both substrate and virtual network models will be described then present VNE problem formulation with both cost and energy consumption as performance metrics.

A. Network Model

- Substrate network (SN): This paper modeled the substrate network as an undirected weighted graph Gs = $(N_s\,, L_s\,, A_{s_n}\,, A_{s_l})$, where N_s , L_s represent a set of substrate nodes and links respectively, and A_{s_n}, A_{s_l} are the attributes of the nodes and links. We assumed that CPU represents the attributes of the nodes, while bandwidth represents the links attributes.

- Virtual network (VN): This represented as an undirected weighted graph $G_v = (N_v\,, L_v\,, R_{v_n}\,, R_{v_l})$, where N_v, L_v represents a set of virtual nodes and links respectively, and R_{v_n}, R_{v_l} are the requirements of the nodes and links denoted by the node required CPU and link required BW.

- Virtual network request (VNR): This paper represented a VN request as VNR $(G_v\,, T_a\,, T_d)$ where T_a is the request arrival time, T_d is the duration of VNR spent in SN and G_v is the virtual network.

- Virtual network embedding (VNE): This is defined as the process of mapping the virtual nodes to the suitable substrate nodes, and mapping virtual links to the corresponding substrate paths in the SN. This mapping process should meet the node and link constraints as follows:

  Node mapping: Mn :{i → J, u → K}

  Link mapping: Ml :{ $L_v \rightarrow P_s$ }

Where, i and u are virtual nodes and J and K are substrate nodes that host virtual nodes. P_s is part of the set that contains the substrate path in G_s. As you can see in (3), it illustrates both CPU and BW constraints, where the CPU provided by substrate node J should be greater than or equal to the CPU required by virtual node I, and the BW of path (J,K) should be greater than or equal to the BW required by the virtual link (i,u) in order to accommodate the VNR demands.

$$\mathrm{CPU}(i) \le CPU(J)\ ,\ BW(i,u) \le BW(J,K)\ ,\ \forall i,u \in N_v\ and\ \forall J,K \in N_s \quad (3)$$

B. Energy Consumption Model

As mentioned before, this paper focus on reducing the embedding cost along with energy consumption. In the presented model, the nodes in the SN will divide in two types. First, active nodes that participate in the current mapping process, as hosting nodes, or still active from the last one. For example, the active nodes in Fig. 1(b) are {A, B, E}. In contrast, idle nodes that still not participating in current mapping process, or already finished its job. Idle nodes in Fig. 1(b) are {C, D}. The energy consumption (E) for VNE process is the energy needed to power the nodes to on state plus the energy needed to host the virtual nodes.

$$E=\begin{cases}\sum_{i=1}^{u}\left(CPU(u).P_l(n_s)\right)+(P_b)\ .\ (N) \\ \qquad \text{if node statues=0} \\ \qquad . \end{cases} \tag{4}$$

Where, N represents set of all substrate nodes that needed to power to ON state, and u represent set of all virtual nodes in VNR. P_b represent server's baseline power and $p_l = p_u - p_b$. Where, $p_u$represent energy consumed when the server reaches its highest utilization [10] [19].

C. Performance Metrics

1) Energy consumption: This is defined as the sum of all the power consumed on each substrate nodes during VNE process.

$$E(vnr)=\sum_{u\in Nv} E.T_d \tag{5}$$

And long term average energy consumption will be defined as following:

$$\lim_{T\to\infty}\frac{\sum_{i=1}^{N} E(vnr,t)}{T} \tag{6}$$

Where, T is process time for the whole VNR, and N is the number of accepted VNR.

2) Embedding cost: This is defined as the sum of all the CPU and BW requirements from the VNR during the VNE process.

$$C(vnr)=(\sum_{u\in Nv} CPU(u)+\sum_{l_{u,i}\in L_v} BW(l_{u,i}))\ .T_d \tag{7}$$

From (5), and (7), we drive the conclusion of the objective functions in our paper that aim to minimize both "E" and "C".

$$\text{Min}\ (\ E + C\ ) \tag{8}$$

3) Embedding revenue: This is the revenue of embedding $\boldsymbol{vnri}$ at time t, and is defined as the sum of all the substrate CPU and BW required by $\boldsymbol{vnri}$.

$$R(vnri,t) = (\sum_{u\in Nv} CPU(u) + \sum_{lu,i\in Lv} BW(lu,i)) \tag{9}$$

Where, $CP(u)$ is the required CPU by virtual node u, and $BW(L_u,i\ )$ is the required bandwidth from virtual link L_u,i

V. Proposed Algorithm

A. EAPSO_Single ISP

1) Particle position initialization: The responsibility of this algorithm is finding near optimal solution for virtual network embedding in single ISP. It starts with particle's position initialization and ends with embedding solution. The particle's position represents candidate solutions for VNE problem. This algorithm takes substrate network as input along with virtual network. SN represented as the following: $G_s = (N_s\ , L_s\ )$. Where N_s is a set of all substrate nodes in G_s, and L_s is the set of all substrate links in G_s.

The algorithm starts with receiving virtual network request. Then constructing Breadth First Search over virtual network, starting with nodes with largest resources (CPU and BW), after constructing BFS tree, each level will be sort in descending order based on virtual nodes resources. At the end, we map virtual nodes starting from root node then from the next level. At SN, we start constructing candidate list for each virtual node: Candidate list constructed by creating BFS over SN starting with a node with highest resources. Then, sorting each BFS level in descending order based on total resources and finally collecting only substrate nodes that have resources higher or equal to requested virtual resources. By constructing BFS and choosing substrate nodes with enough BW to accommodate virtual nodes required BW, only nodes with enough BW will be considered, thus virtual link mapping will be considered at same time of creating substrate candidate list. After creating candidate list, initializing particle position vector stage will begin where each virtual node will choose from its candidate list, the host that could map to. Each node selected from the candidate list should update its remaining resource value.

2) Energy: Aware Virtual Network Embedding algorithm

This algorithm depends on checking the feasibility of each particle position. Particle considers feasible if there is at least one path in SN for every virtual link. If the particle is feasible, then it should be updated as the following:

$$v_i^d = p_1 v_i^d + p_2\left(pBest_i^d - x_i^d\right) + p_3\left(gBest - \ x_i^d\right) \tag{10}$$

$$x_i^d = x_i^d \times v_i^d \tag{11}$$

Otherwise, particle should be remapped in way that each virtual node will reselect nodes from its candidate substrate list as in subsection "Particle position initialization". After checking the feasibility, the fitness function of each particle should be calculated.

However, because of the nature of working in discrete workspace, PSO original operation should be modified to fit into presented Energy-Aware VNE algorithm. The modification will be as the following: The velocity will represent as vector generated randomly from each virtual node's candidate substrate list. Ex: $V = (v_1, v_2, v_3, v_i)$, where i represent the order of virtual nodes in VNR. Candidate substrate list of virtual node in dimension i contains neighbor nodes of substrate node in dimension i.

"X" represents the position vector.

Ex: $X = (x_1, x_2, x_3, x_i)$.

Where, i represent the order of virtual nodes in VNR.

- Subtraction (-): This operation depends on the fitness function of position X_i, pBest and gBest to apply exchanging rules. It works as by Calculate fitness function of X_i, pBest and gBest and then Seek for the conflict between two clauses. After that, change the values from the solution with worst fitness according to the position of the conflict values.
- Addition (+): $v_i p_i + v_j p_j$ indicate that substrate nodes will be kept from v_i with probability of p_i, and kept from v_j with probability of p_j. The selection technique we used called "Roulette Wheel Selection".
- Multiplication (*): This operation maps the virtual nodes that currently mapped to substrate nodes from X_i to the corresponding substrate nodes in V_{i+1}. If the same dimension in V_{i+1} and X_i has the same node, the virtual nodes should reselect the substrate nodes from its candidate list as the following:

$$X_i * V_{i+1} = (A, B, A) * (A, D, C) = (N, D, C)$$

Where, N is new selected node from substrate candidate list.

Both position and velocity update will be as the following equations:

$$v_i^d = p_1 v_i^d \oplus p_2 \left(pBest_i^d \Theta\, x_i^d\right) \oplus p_3 \left(gBest^d \Theta\, x_i^d\right) \quad (12)$$

$$x_i^d = x_i^d * v_i^d \quad (13)$$

p_1, p_2, p_3 are random numbers generated in condition of: $p_1 + p_2 + p_3 = 1$

B. EAPSO_Distributed Clouds

In this part of the algorithm VNR shall be partitioned to several sub-graphs to cope with problems consequent from lack of available resources or clients geographical constrains violation. VNR will be coarsened to smaller sub-graphs then assigning phase will start. This algorithm composed of three main methods: Coarsening graph, Un-coarsening graph, and Construct graph (Algorithm 1).

1) Coarsening VNR phase: In this phase, the original graph will be coarsened to several yet smaller sub-graphs. Each of these sub-graphs composed of several vertices grouped in single node. The weight of coarsened node equal to the sum of vertices contained. The proposed algorithm follows Heavy Clique Matching (HCM) to obtain coarsen graphs [16], [20].

2) Uncoarsening phase: Before sending the coarsen node to suitable DC, each node should be projected to its initial graph. In this case the coarsen node assigned to DC in form of sub-graph. Uncoarsening function responsible of finding all virtual nodes that collapsed inside the coarsen node C_n. The obtained nodes will pass to Construct_graph function.

3) Construct graph phase: In this phase, each coarsen node will be reconstructed as graph before it sent to the suitable DC. As seeing in Algorithm2, using same approach as the one used in single ISP, it starts with constructed BFS tree from the coarsen graph. In the created BFS tree, each coarsen nodes in each level will be sorted in descending order based on their requested resources. Starting from root node, each coarsens node will reconstructed by creating sub-graph from uncoarsen nodes and links connecting them. Each sub-graph will be assigned to SN that copes with its requirements. If assign function ends, each SN will start mapping its assigned VN as single ISP scenario, otherwise Algorithm 2 will terminate and assign_flag return false.

Algorithm 1: *Energy-Aware Virtual Network Embedding Algorithm*

Input: virtual network $G_v = (N_v, L_v)$.

Substrate network $G_s = (N_s, L_s)$.

Output: Embedding solution.

Begin

1: Initializing particles population.
2: Initializing pBest and gBest for each particle.
3: While stopping criteria in not satisfied.
4: For each particle i do {
5: Get fitness function $f(x_i)$ for particle I .
6: If($particle\ position\ .feasable()$) then {
7: Update particle position and velocity according to Equations (12), (13).
8: Else
9: Re- initializing its position, and recreate velocity vector randomly.
10: } End if
11: } End for
12: Get $pBest_i$ and $gBest$
13: If $f(x_i) < f(pBest_i)$ then
14: Set x_i as new personal best position for particle i.
15: If $f(pBest_i) < f(gBest)$then
16: $set\ pBest_i$ As new global best position.
17: End if
18: End while
19: Embedding solution is final $gBest$.

End

Algorithm 2: *EAPSO_distributed clouds*

Input: virtual network to embed $G_v = (N_v, L_v)$.

Substrate networks $G_s = (N_s, L_s)$.
N_s is substrate network to assigned to.

L_s: All substrate links between substrate networks.

Min_resource: minimum available resource in SN.

Output: assign_flag: VNE success flag.

Begin

1: G_c=coarsen (G_v,min_resource).
2: Build BFS tree of G_c starting with coarsen node with highest resources as root.
3: Sort nodes in each level in descending order based on their required resource.
4: For each node $N_{c\_}$ in the sorted list construct sub_graph after obtaining it's uncoarsen nodes.
5: Un_coarsening()
6: Sub_G=Construct_graph ($N_{c\_}$).
7: If (assign (sub_G,G_s)).
8: Then.
9: assign_flag=true.
10: Return.
11: Else.
12: Assign _flag=false.
13: Return
14: End if
15: End for
End

VI. Evaluation

In order to support the presented assumption and evaluate the efficiency of the proposed algorithm, extensive experiments conducted to evaluate proposed algorithm against the following algorithms: HCM [15], RW-MaxMatch [16], BFSN-HEM [17], AdvSubgraph-MM [13], BFSN [17], AdvSubgraph-MM-EE [13], and AdvSubgraphMM-EE-Link [13].

A. Environment Setting

Using Waxman generator, substrate network topology is generated with 100 nodes and 500 links. Bandwidth of the substrate links are uniformly distributed between 50 and 150 with average 100. Each substrate node is randomly assigned one of the following server configurations: HP ProLiant ML110 G4 (Intel Xeon 3040, 2 cores X 1860 MHz, 4 GB), or HP ProLiant ML110 G5 (Intel Xeon 3075, 2 cores X 2660 MHz, 4 GB). In addition, 1000 Virtual network topologies are generated using Waxman generator with average connectivity 50%. The number of virtual nodes in each VN is variant from 2 to 20. Each virtual node is randomly assigned one of the following CPU: 2500 MIPS, 2000 MIPS, 1000 MIPS, and 500 MIPS, which are correspond to the CPU of Amazon EC2 instance types. Bandwidths of the virtual links are real numbers uniformly distributed between 1 and 50. VN's arrival times are generated randomly with arrival rate 10 VNs per 100 time units. The lifetimes of the VNRs are generated randomly between 300 and 700 time units with average 500 time units. Maximum allowed hop is set to 2 and maximum backtrack is set to 3*n, where n is the number of VN nodes. Generated SN and VNs topologies are stored in brite format and used as inputs for all mapping algorithms.

B. Experiment Results

In case of energy consumption, it represents energy consumption comparison according to achieved resources starting from t=5000 until t=10000. Taking look in Fig. 2, it shows that energy at time T=5000 equals to 1 kilowatt and start to fall until T=9000 where its reach 0.8 kilowatt. By observing energy at T=7000 and T=9000 the algorithm presents rise of consumption at T=9000 even though acceptance ratio in both time is equal to 29% (Fig. 3). The reason behind this variant in energy consumption goes to the increase in number of achieved resources at T=9000 with 13.23% (Fig. 4). On the other hand, by comparing proposed algorithm with previous VNE algorithms, it can be noticed that EAVNE_PSO scores lowest consumption among all.

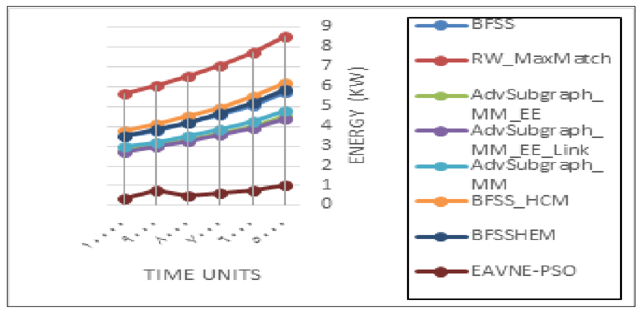


Fig. 2. Energy consumption.

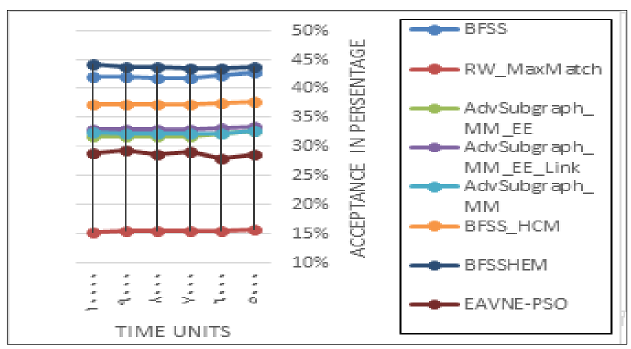


Fig. 3. Acceptance comparison.

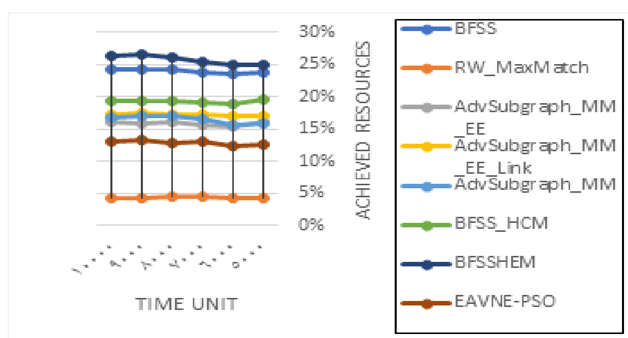


Fig. 4. Achieved resource comparison.

Fig. 5 shows the regression of long term average revenue as time increase, this goes to the fact that while time pass, more VNR will finished and depart from SN, thus decreasing overall revenue at that point. In comparison to the previous VNE algorithms, EAVNE_PSO outperforms RW-MaxMatch with 1000 "in money unit" while maintaining below the remaining algorithms.

From Fig. 6, the proposed algorithm at T=5000 score highest value of R/C over 96% which is the same time of highest registered revenue. While by comparing value at T=6000 and T=7000 it is clear that even T=6000 score higher revenue than T=7000, it encounters drop of R/C value. This drop can be explained that cost of mapping VNRs at T=6000 is higher than one in T=7000. From the previous, it noticed that highest R/C means smaller gap between value of revenue and cost and vice versa. Fig. 6 presents that proposed algorithm R/C values did not exceed any algorithms that involved in the experiment. In order to improve revenue over cost, proposed algorithm allows more than one virtual nodes to map on same substrate node, thus decrease cost of mapping these nodes since cost of mapping link between them is 0.

EAVNE_PSO has significant increase comparing to RW-MaxMatch with 15% acceptance ratio while still not outperforms the remaining algorithms witch reach to 44% as in BFSSHEM. The reason behind the rejection of VNRs that reach to over 85% as in Fig. 7 goes to the lack of available resources either CPU or BW as showing in Fig. 8 and 9. As showing in Fig. 3, at time 9000 the availability of CPU decreases due to the fact that in that time the acceptance ratio increased to 28%. From this point, the proposed algorithm highlights the fact that while experiment time increase, the acceptance ratio will rise due to the fact that by time passing more VNRs will depart the SN and therefore the resources availability will increase.

Even that it looks like proposed algorithm has low acceptance ratio among other VNE algorithms (except RW-MaxMatch), it must be emphasized on fact of the heuristic nature of the proposed algorithm in finding near optimal solution instead of exact one. It gives the proposed algorithm the advantage of working in larger networks (more than 200 nodes) and find near optimal solution in reasonable embedding time, in contrast of exact solution algorithm which take exponential time to find solution. Therefore, proposed algorithm will be even more efficient in larger networks.

From Fig. 10, the VNE time for the proposed algorithm varies between 4300 and 4500 milliseconds. This range falls between times of AdvSubgraph-MM, AdvSubgraph-MM-EE and AdvSubgraph-MM-EE-Link which score highest VNE time reach to 50000 milliseconds in AdvSubgraph-MM-EE-Link algorithm and times of the remaining algorithms that start from 300 milliseconds in BFSS and drops from there.

Through further observation in EAVNE_PSO VNE time, it perceives that times have almost steady rate with slight variation. This is due to the nature of EAVNE-PSO algorithm in finding near optimal solution. The proposed algorithm goes through the same steps and iterations for every VNR. It starts from creating fixed number of candidate solutions and run them through fixed number of iterations.

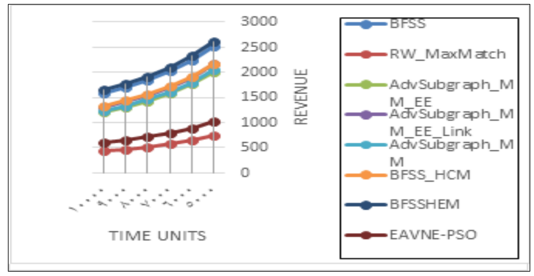


Fig. 5. Revenue comparison.

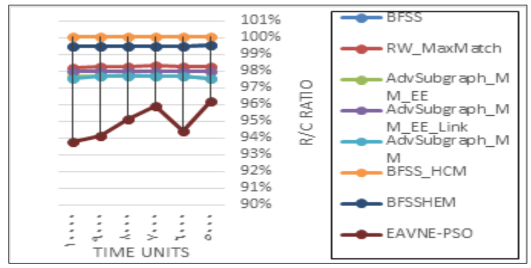


Fig. 6. R/C comparison.

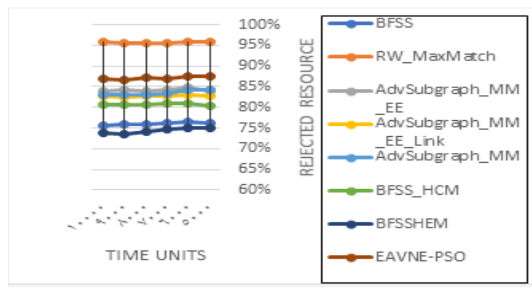


Fig. 7. Rejected resource comparison.

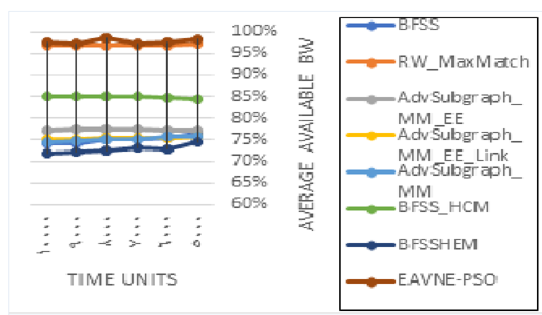


Fig. 8. Average available CPU comparison.

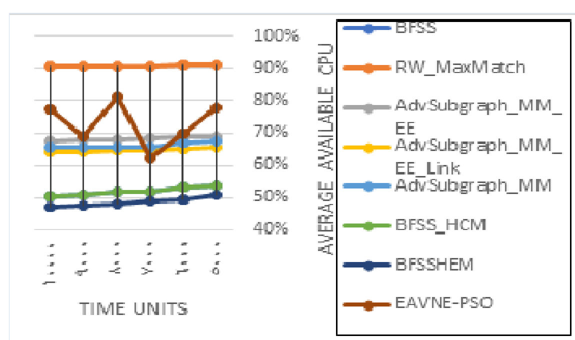


Fig. 9. Average available BW comparison.

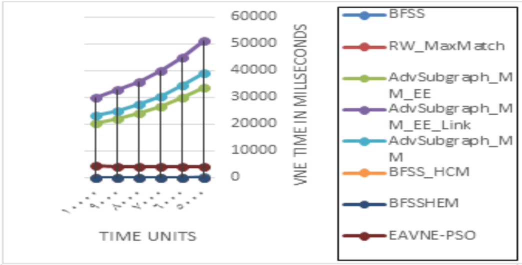


Fig. 10. VNE time comparison.

VII. Conclusion

This paper tackled the importance of cloud computing and network virtualization to fulfill the growth demands for resources provisioning. One of the most important issues in resources provisioning is how to map virtual resources to corresponding physical one. This issue defined as VNE problem. VNE considered as NP-hard problem and it gain a lot of attention last few years. This paper proposed Energy Aware Virtual Network Embedding in Distributed Clouds. The proposed algorithm aims to find near optimal solution based on modified Particle Swarm Optimization algorithm. For the distribution purpose, VNR will be partitioned in to sub-graphs. After partitioning phase is over each sub-graph will be sent to the suitable DC where modified PSO is initiated.

The proposed modified PSO reduce both embedding cost and energy consumption by finding embedding solution that contains least idle nodes that needs to be powered on. In addition, by virtual node consolidation along with setting maximum allowed hop to 2 to prevent the situation of placing two neighbor nodes far away from each other, thus reducing embedding cost.

After conducting extensive experiments to evaluate the efficiency of the proposed algorithms, it shows that EAVNE-PSO algorithm outperform RW-MaxMatch algorithm in energy consumption, revenue, acceptance ratio, achieved and rejected resources. After extensive observation, the proposed algorithm achieved acceptance ratio that represent 70% of highest acceptance ratio among the tested previous works “BFSSHEM”, while energy consumption is 9% less. In addition, the number of accepted VNRs along with the size of accepted VN has a significant impact on revenue gained and energy consumption path splitting technique in link mapping is planned to be adopted in the future work. This technique will decrease rejected BW by partitioning a single virtual link BW to be mapped through different substrate paths. Furthermore, virtual nodes migration will add further improvements in energy and cost preservation. By moving virtual nodes from under- or over-utilized hosts, it can increase the chances of switching underutilized hosts to idle mode and consolidating virtual nodes in the same host.

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A Tri-Level Industry-Focused Learning Approach for Software Engineering Management

Anis Zarrad
College of Computer Science and Information Systems
Prince Sultan University, Riyadh 11586, KSA
Riyadh, KSA

Yassin Daadaa
College of Computer and Information Sciences
Al Imam Mohammad Ibn Saud University (IMSIU)
Riyadh, KSA

***Abstract*—Most engineering classes in higher education rely heavily on the traditional lecture format, despite the fact that a number of investigations have shown that lectures, even when given by good lecturers, have limited success in helping students make sense of the engineering practices they are learning. Recently, the Software Engineering Body of Knowledge (SWEBOK) highlighted the importance of professional practice in producing high quality engineering programs. The integration of industry links in teaching pedagogy is essential. In this paper, the authors introduce a new industry-oriented tri-level teaching approach in order to offer students the opportunity to be involved in industry projects and gain important work experience during the academic period. To prioritize industry hands-on activities for students and shape the traditional classroom toward an industry environment, three entities are involved in this approach: industry guest speakers, teachers, and students. Traditionally, guest lecturing is centered on the speaker, who delivers a presentation and follows with a short question and answer session. Students are often passive learners in this process. A blended learning approach was therefore integrated between all entities to allow more flexible learning opportunities, wherein students participated in each step of guest lecturing, including preparation, questions, and reflection. A software project management case study was introduced to measure students' performance and satisfaction.**

***Keywords*—Component; software project management; education; student rubric assessment; student learning outcomes; industry activities; guest lecturing approach**

I. Introduction

Since the introduction of computers in the 1940s, the use of software has grown dramatically and has become one of the most important fields in the manufacturing industry. The software engineering (SE) discipline was first introduced in 1968, at the NATO Conference on Software Engineering [15]. Despite more than fifty years of effort made to develop various teaching theories, support tools, and practical SE, the SE field continues to lack direction and effective teaching methods.

Most students find it difficult to understand and retain software development processes. The discipline is typically taught using traditional teaching methods, where students must attend lecture classes that are followed by discussion and questions. We feel that using traditional teaching approaches, such as case studies [8], [9], teacher-centered methods [7], and student-centered methods [7], makes it quite difficult for students to understand software development obstacles and the management aspect in such a short duration. Engineers must be practical, but cost and logistics act as barriers to providing undergraduate and graduate engineering students at universities with practical industry experiences. The long time-frames of major real engineering projects and the higher associated cost result in students only seeing a snapshot of the entire project life cycle. Recent trends in SE education recommend that SE students acquire knowledge in both software development and its management. It is necessary that the project should. In this work, we focus on software project management (SPM).

Currently, most SPM teaching techniques involve teacher-centric classrooms, as presented in many course specifications [1]-[5]. Challenges exist in teaching a SPM course, as it may be uninteresting and frustrate students when taught theoretically [23], especially when using the traditional approach. The traditional approach uses a one-way information flow in a closed classroom environment, keeping information transfer in the low levels of Bloom's taxonomy (Fig. 1).

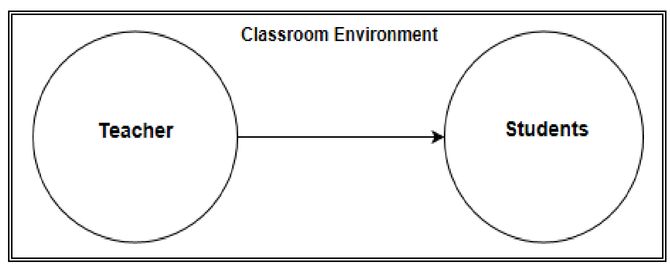

Fig. 1. Traditional teaching method, showing one-way information flow in a closed environment.

The authors in [41] discovered that students face difficulties understanding theories and concepts in SE courses when the method of teaching is straight forward and monotonous. This was supported by Grist and Myers [26], who stated that the traditional theory-based classroom approach is considered conventional and passive, which may result in dullness.

Course exit survey results have shown areas of deficiency related to real hands-on activities and practices. Statistical results for the 2014 – 2015 (35 students) and 2015 – 2016 (33 students) academic years in a software management course offered at Prince Sultan University are shown in Fig. 2. A scale from 1 (not satisfied) to 5 (fully satisfied) was used to indicate students' satisfaction with the following areas:

1) Application of industry-strength tools and techniques for real software project planning.

2) Use of practical applications of real project management to formulate efficient strategies.

This course at Prince Sultan University is open to junior and senior students in SE, information systems, and computer science majors. The class covers all management aspects: scope, time, cost, communication, integration, resources, risks, quality, and procurement. A total of 27 students declared that they were somewhat satisfied or below in the 2014 – 2015 academic year (Fig. 2). More than 77% were not satisfied with their management knowledge and skills due to the lack of industry practitioners. These survey results are in agreement with those obtained in [10]. Moreover, the authors of SWEBOK [16] mention and focus on the importance of management topics in the SE discipline. In addition, many SE curriculums [1]-[5] have ignored the SPM topic. This statement is well supported by [25], which stated that “the abstract nature surrounding the management of IT systems makes the concept difficult to teach in a classroom”. The teaching pedagogical tendency should therefore emphasize the entire project life cycle using real projects/cases to successfully carry out the course outcomes.

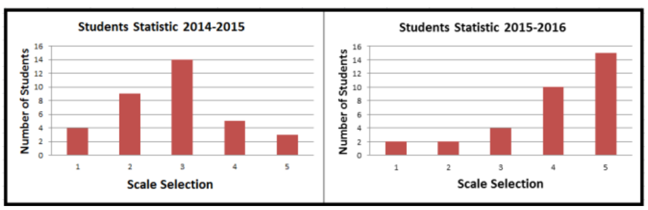

Fig. 2. Course exit survey statistics for two academic years in a software management course, 2014 – 2015 (35 students) and 2015 – 2016 (33 students). Traditional teaching methods were used in 2014 – 2015, whereas a proposed tri-level teaching approach was followed in 2015 – 2016. Graphs indicate students’ satisfaction (1 = not satisfied, 5 = fully satisfied) with their training in real-world software project planning and management.

In this paper, we present a tri-level teaching approach to ensure effective and meaningful learning in SPM courses. The proposed approach relies on a blended learning practice [27] grounded by guest-lecturing apprenticeships. The resulting environment provides learners with the necessary knowledge and skills, as well as an understanding of real management activities in the industry. Survey results for the 2015 – 2016 academic year, when the proposed tri-level approach was used, indicated satisfaction from more than 75% of students (Fig. 2). The guest speaker’s profile, qualification, and skills have an important impact on the teaching methodology success. To cover a real industry project timeframe, a blended learning model is used to cement what students do on their own and allow them to apply their knowledge to industry case studies presented by the guest speaker. The involvement of professionals from an industry environment in introducing and supervising students during their final project in a very industry-focused way changes students’ perceptions about the SPM course and improves their management skills. Another important benefit of the proposed approach is to help students become familiar with the professional environment in an academic environment [8], including learning communication and operations practices. The blended learning pedagogy [27] has been shown to increase student engagement and significantly improve learning. To engage students in synthesis and analysis levels, it is very beneficial to combine regularly-scheduled, on-site classroom meetings with professional guest speakers and online learning activities using Moodle [42] and Calendly [41] to set meeting times and open discussions with the guest lecturers. The authors of [21] indicated the importance of the industry environment in providing core and advanced engineering knowledge and skills for the SE discipline. According to Jennings et al. [19], guest speakers can be used to enhance the sustainability of quality pedagogical methodologies and can offer real-world learning opportunities for students, as compared with traditional classroom learning methods. Hussein and Rolstadås [28] emphasized the importance of using multiple learning methods when delivering company tailored education programs.

The approach proposed herein attempts to bring industry environment into the classroom through guest lecturing, giving students the opportunity to be involved in industry projects and gain important work experience. This paper is organized as follows: Section II presents related works; Section III provides a brief introduction of the proposed teaching practice and environment; Section IV highlights the data analysis and results; and Section V concludes the paper.

II. Related Works

Many pedagogical strategies using guest lectures in SE education can be found in the literature. It is acknowledged that students learn more effectively when real project-based learning is incorporated into the learning process [7]. The authors in [10], [17] focus on the incorporation and selection of software projects in an industrial context to improve students’ motivation and management skills. Both approaches [10], [17] showed promising results; however, the quality of the project output will depend not only on real project selection, but also on the execution environment and collaboration practices. Inviting a project manager to give a series of talks as a guest speaker from the industry and to supervise students enrolled in a SPM course meant to implement real activities can therefore have a good an impact on students’ interest and management skills. Students in SE programs [6] appear to have a negative attitude about project management, and lack management and technical skills. SPM courses typically depend upon knowledge derived from several disciplines, including technology, computer science, engineering, sociology, and economics. In [24] authors proposed a quantitative methode for research purpose in writing their dissertation (research) proposals.

The authors of [18] proposed the use of guest lecturing to promote active learning through a constructivist approach [20]. Compared to the traditional environment, where students are often passive learners, the constructivist theory can yield remarkable benefits, adding value to the student learning experience. That study investigated the guest lecture approach in an online learning environment, however, where presentations are given using synchronous communications due to the difficulty of coordinating time between the speaker and students. As a result, students did not appear to benefit from guest speakers, due to the lack of face-to-face interaction.

Moreover, such lectures require much time and effort to deliver.

Krishna [22] described an interesting teaching method for project management using simulation. Project management simulation is used for what–if analysis, helping managers promote effective decision-making in real projects. It is an interactive learning group activity, where students try to solve real-world projects involving factors such as scope, time, schedule, and resources [23]. Simulation has been appropriated for many disciplines, including health and the military, although the technology can become confining for some junior students. Bassem [40] proposed a similar approach to ours, based on a blended teaching approach with a company presentation component. He demonstrated in detail how blended learning practices can be applied in order to create a learning environment that facilitates involvement and engagement of learners, providing learners with a sound understanding of project complexity. The aim of the invited guest speaker is to give the students some practical insights. The incorporation of games can allow students to emphasize fun and ignore serious learning. Additionally, participation requires students to invest energy in all phases of the learning process.

Many other teaching approaches for project management based on games are proposed in the literature. Such approaches encourage exploration and trial-and-error actions with the possibility of instant feedback, therefore stimulating curiosity and learning. The authors in [29] described the theoretical foundation of games as a teaching approach. The focus was on the importance of direct experience, reflective observation, and appropriate feedback in a continuous process of goal-directed action [30]. The authors showed that summative assessments, such as assignments, case studies, and exams, provide training and knowledge, whereas games offer direct experimentation and observation.

Many works [31]-[35] have reported games as an efficient learning approach in project management courses. Some of these proposed approaches [31], [32] rely heavily on a computer environment, whereas Klassen and Willoughby [33], Hood [34], and Bohn and Lynch-Caris [35] reported on classroom-based simulation games using a medium other than computers. An effectiveness study of the game learning approach in management courses remains to be verified. In a typical approach, the project is first modelled in a software tool along with uncertain variables. A simulation is then run to check the different possible outcomes and their probability as a result of different inputs for the uncertain variables. Pfahl et al. [36], [37] conducted several experiments to measure the effectiveness of game teaching approaches. They concluded that games are a very useful approach for learning about issues in SPM. Other works [38], [39] concerning learning behaviors, however, have led us to infer that there is no emphasis on teaching skills or content, only a focus on social behavior. In addition, skills concerning computation technology are a necessity for all learners.

III. Proposed Teaching Practice and Environment

In this section, we present our environment study and the detailed implementation of our proposed teaching approach.

A. Study Context and Environment

This study took place in a SPM course at Prince Sultan University, Saudi Arabia, during the academic years 2014 – 2015, 2015 – 2016, and 2016 – 2017. The target group of the course included full-time university students working on a degree in Software Engineering, Information Systems, or Computer Science. The course used two different teaching approaches. In 2014 – 2015, a traditional classroom was used, whereas in 2015 – 2016 and 2016 – 2017, a proposed tri-level teaching approach was applied. Effectiveness (knowledge, skills) and students' motivation were analyzed following each approach.

The total number of students enrolled in the course was 35 students in 2014 – 2015, 33 students in 2015 – 2016, and 22 students in 2016 – 2017. The course prerequisites are IS241: Database Management and IS231: System Analysis and Design. The purpose of the proposed approach was to expose students to the industry background in an academic environment, where appropriate real-world decisions based on case studies would be supervised and evaluated by professionals throughout the semester.

In this study, we used a graded rubric [13], [14] approach and an exit course survey to measure the learning outcomes and students' performance. Course learning outcomes were mapped to program learning outcomes and evaluated. Peer observation was also implemented to evaluate the efficiency of the proposed teaching method, based on the Higher Education Academy peer review process [12].

B. The Proposed Tri-Level Teaching Approach

Several instructional methods were used in the course. In addition to classroom lectures and other supporting materials, such as handouts, lectures notes, exercises, papers, written project reports, and quizzes, the course relied heavily on guest speakers to demonstrate and discuss real industry projects. The proposed tri-level teaching approach is presented in Fig. 3. We believe that much of the effective teaching that results from this approach is due to the fact that the students are supported by both the teacher and guest speakers, and both classroom and industry environments are well integrated into the whole course experience.

Students apply their knowledge and skills in real-world industry case studies and interact with professionals in the management field and real clients. To facilitate this, we move from the traditional academic environment to an industrial environment. The overall idea is to expose students to the industry background in an academic environment.

The approach implementation highlights the relevance of course content by pointing out its significance in the real world and introducing real hands-on case-studies that are presented, supervised, and evaluated by an experienced project manager from the industry. Material relevance and real hands-on activities are key determinants of student motivation. If students feel motivated, they are more likely to take an active role in their own learning, which in turn can lead to better knowledge acquisition.

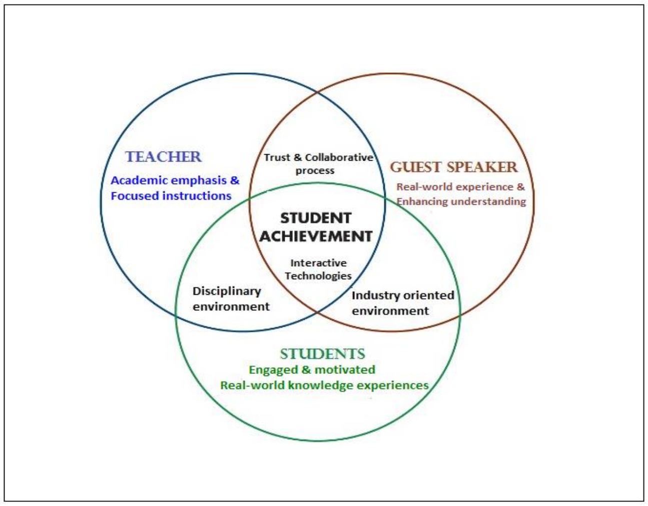

Fig. 3. Proposed tri-level teaching practice.

With the agreement of the guest speaker, a peer observation was completed during this visit. A screenshot of the observation report is shown in Fig. 5. The observation focused on students' interest, motivation, and participation. The observation agenda included the following items:

- Observe student engagement during the case study activity Relates information to future, practical (real-world) application Shares up-to-date info in field.
- Observe student motivation.
- Observe guest speaker–student interaction Students respond positively and/or engage effectively with guest speaker questions.

The purpose of this research action was to examine the impact of both the guest speaker and the use of a real case study on students' interest and motivation in the SPM course.

The majority of SE students hope to enter the professional management field in some way. Professional guest speakers can motivate students by linking their course content to students' intended professions, and by pointing out how the skills and knowledge gained in class will help them after they graduate. The instructional components of the proposed tri-level approach are:

Lecture: These are regular face-to-face lectures conducted using different teaching aids, such as PowerPoint presentations and notes taken in the class. All materials are available on the LMS course web site.

Textbook: Essential Scrum: A Practical Guide to the Most Popular Agile Process

Author: Kenneth S. Rubin

Publisher: Addison Wesley Professional

Summative Assessment: The purpose of summative assessment is to evaluate student learning at the end of an instructional unit by comparing it against some standard or benchmark. In this course, we used assignments, quizzes, group projects, case studies, a midterm exam, and a final exam.

Formative Assessment: The purposes of the formative assessment are to monitor student learning and target areas that require work. We used online discussion and a forum.

LMS Moodle [43]: This is an educational software helping teachers and trainers create and deliver effective online learning environments used by millions world-wide. We used Moodle as a learning management system to upload all course materials, announcements, assessments, etc.

Guest Speaker: "Mr. Eng", a functional project manager in the telecommunication industry, was invited as a guest speaker to offer three talks to the students and present real case studies with the intention of improving their management skills [8], [9]. Continuous feedback concerning the case study implementation was given by the guest speaker to the students. As an instructor, I prepared the students before each visit and made sure we covered the discussed materials before the guest lecture. This further stimulated deep conversations concerning the topic and avoided awkward silence during the session. Three sessions were scheduled, and each session was structured to engage the students in thinking and reasoning throughout the class period.

The outline of the talk for the first visit (week three) was as follows: 1) an introduction to break the ice; 2) an open discussion about the distinction between management and administration, presenting both theories from Mary Follett and Sheldon [11]; 3) an overview of the project management process with a focus on the ways in which project management may vary significantly from one organization to another; and 4) "Mr. Eng" presented a real case-study about managing the development of a new billing system for the SFR Telecom Company. This case study was used throughout the semester, beginning with the preparation of the business case and project charter, followed by the development of work breakdown structure, and finally the implementation of the whole project using Microsoft Project.

The outline of the talk for the second visit (week seven) was as follows: 1) students presented a progress report about the case study discussed in the first visit; 2) "Mr. Eng" presented a fairly easy-to-implement project management process using the triple-constraint model and Microsoft Project; and 3) an open discussion occurred concerning problems faced in real projects, such as budget, time, and the closing process. Students practiced many approaches to shrink resources and tighten deadlines, in order to make project management more important and attract students to the management field.

The outline of the last visit (week 15) involved students presenting their final product, as expected by following the planning schedule. The final presentation occurred at the end of the semester after we had covered all materials necessary to complete the project successfully. The project assessment scheme was based 50% on the guest speaker and 50% on the course instructor. "Mr. Eng" then gave constructive feedback to the students.

IV. Analysis and Observation

Typically, students enrolled in SE possess excellent knowledge of computer and information sciences, but their skills are weak in the field of business practice and management. There is therefore a need to focus on the subject of management and avoid repeating knowledge related to software development that has already been learned.

It important to mention that SPM courses include copious amounts of material for students to consume due to the numerous definitions and basic concepts in management that must be covered, and the fact that no business knowledge is acquired frustrates and discourages students. As a first step, we put extensive effort into lessening the amount of material to an appropriate volume and reducing the required texts.

Students had difficulties applying what they learned in a real-world context (Fig. 2). It is therefore important for students to clearly see how their coursework connects to their interests and how to apply their management knowledge to real-life problems. The program learning outcomes and course learning outcomes (CLO) for the proposed course are mapped in Fig. 4. Special focus was placed on CLO 6.

Course Code	SE423	Import

Course Learning Outcomes (CLO)	
CLO 1	Describe the motivation for, basic principles of, and terminology of project management.
CLO 2	Develop feasible project plans applying appropriate concepts in software estimation, resourcing, scheduling and software risk management
CLO 3	Apply basic project management principles in order to achieve project success
CLO 4	Apply schedule and cost estimation, Function Point Analysis (FPA), Object-Oriented FPA, schedule and cost estimation with COCOMO II
CLO 5	Apply project control techniques that help find solutions to problems fast – enabling you to bring your project back on track as quickly and cheaply as possible
CLO 6	Apply industry-strength tools and techniques for real-project planning and control, including size and cost estimation, scheduling, and risk management
CLO 7	
CLO 8	

Mapping of CLOs with PLOs

	PLO A	PLO B	PLO C	PLO D	PLO E	PLO F	PLO G	PLO H	PLO I	PLO J	PLO K
CLO 1	x					x					
CLO 2	x			x						x	
CLO 3	x	x		x						x	
CLO 4									x		x
CLO 5	x	x								x	
CLO 6	x		x	x	x		x	x			x
CLO 7											
CLO 8											

Note: Use "x" for mapping a CLO with a PLO

Terminology used	
CLO	Course Learning Outcomes
PLO	Program Learning Outcome

Fig. 4. Mapping of program learning outcomes (PLO) and course learning outcomes (CLO) for software project management education.

The proposed tri-level teaching practice strategy is adapted to bring industry to the classroom. The authors of [8], [9] showed the importance of using decision case studies in engineering education to expose students to real-world issues with which they may be faced.

A. Data Collection

Information collected from exit course surveys (Fig. 2) showed that students face some difficulties in applying their learning knowledge to real-life practice projects. We used a grade-based rubric system implemented in our department to automatically convert grades to rubrics. This means that CLO achievement was measured based on the number of students whose achievements were categorized as "accomplished expectations", based on the rubrics. Four levels with three criteria were used for this rubric (Fig. 5).

BE	Below Expectations		
DE	Developing Expectations		
ME	Meeting Expectations		
AE	Accomplished Expectations		
	Section's Satisfaction		
0	0.00	BE	Less than 60% of students are achieving the Satisfactory level (ME) or above
1	60.00	DE	60% to 69% of students are achieving the Satisfactory level (ME) or above
2	70.00	ME	70% to 89% of students are achieving the Satisfactory level (ME) or above
3	90.00	AE	90% or more of students are achieving the Satisfactory level (ME) or above

Fig. 5. Rubric levels used to assess achievement of course learning outcomes.

Equation (1) shows the details of the rubric calculation:

$$R = \frac{\sum_{i=1}^{N}(m_i - min_i)}{\sum_{i=1}^{N}(max_i - min_i)} \quad (1)$$

Where m_i is the grade for the i^{th} criterion, min_i is the minimal possible grade for the i^{th} criterion, max_i is the maximal possible grade for the i^{th} criterion, and N is the number of criteria used to compute the rubric. The formula per assessment is:

$$\text{(Number of students achieved AE and ME) / (Total number of assessed students)} \quad (2)$$

Statistical results showed "Below Expectations" for the academic year 2014 – 2015, due to the lack of practical work (Fig. 6). The aggregation of CLO 6 using both direct and indirect assessments was below expectations (53%).

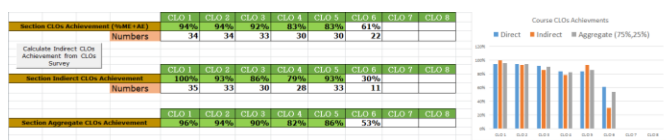

Fig. 6. Rubric results for the academic year 2014 – 2015.

Similar data were collected during the academic year 2015 – 2016 to observe the impact of the proposed approach using real hands-on activities from the industry. The rubric analysis showed interesting results of "*Meeting Expectations*" (Fig. 7).

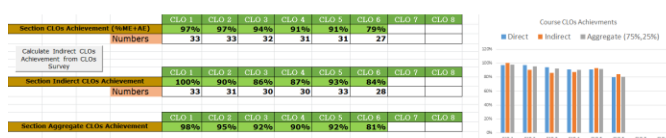

Fig. 7. Rubric results for the academic year 2015 – 2016.

Based on the rubric analysis, the impacts of the guest speaker and the use of real case studies were clearly reflected in the students' outcomes. Comparing Fig. 7 to Fig. 6, we achieved an improvement of approximately 40%. The number of students increased from 11 to 27 students. Similar results were found in 2016 – 2017, but these are not included in this paper due to space constraints.

B. Data Analysis

The rubric completed in the academic year 2014 – 2015 showed that students faced difficulties applying industry tools to real projects. Additionally, students complained about the lack of practical tools, such as project planners and practical examples of management using Microsoft Project.

After applying the proposed tri-level teaching approach, the results collected in the academic year 2015 – 2016 showed an improvement in CLO 6, as expected. Student cohorts and rubrics showed that students' experience and motivation improved by approximately 40%. In addition, this approach enhanced the teaching pattern quality, adapting new tools on the market and being reflected in the course content for the following semester.

Students gained professional practice to achieve excellence in their future professional lives. The most problematic issue in this strategy is how to find a guest speaker who possesses specific experience, and is willing to do student follow-up case studies and offer a series of talks over the course of the semester.

The hands-on activities using a real case study proposed and supervised by an invited guest speaker overcame the disadvantages mentioned in [10], [17]. Students were confronted with new and very challenging ideas by professionals from the industry.

Survey and rubric results completed in 2015 – 2016 and 2016 – 2017 showed better outcomes compared to results collected in previous semesters. Furthermore, external peer observation confirmed the benefit of the guest speaker and varying viewpoints in classroom. "Mr. Eng" has strong experience in project management, as well as good teaching experience, and was easily able to draw the students' attention. The importance of peer review is that it presented an independent opinion concerning the proposed teaching approach being adopted in SPM courses at Prince Sultan University.

V. Conclusion and Future Actions

Overall, the use of the proposed tri-level teaching approach improved students' motivation and interest in the software management field. Having an experienced project manager from the industry field as a guest speaker, to offer a series of talks and supervise students in their final project, changes the environment from a traditional academic environment to an industry environment, discharging students from classroom routines. Students show interested behavior and are motivated during the whole semester. Exit surveys and grade-based rubric calculations showed remarkable achievement compared to previous years when the course was delivered using a traditional classroom approach.

Inviting a guest speaker to the classroom switches things up from the normal traditional routine, giving students an opportunity to interact with professionals and apply their learning in real case studies proposed by the guest speaker. Students receive the opportunity to engage in real hands-on activities with their peers. Additionally, the external peer-review report recommended this move. The field of engineering requires effective professional activities in order for engineers to feel comfortable with their capacity to be leaders or managers. The educational approach proposed here could also be implemented for school children, to develop future engineering students.

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Design and Implementation of a Communication System and Device Aimed at the Inclusion of People with Oral Communication Disabilities

Dr. Máximo López Sánchez
Computer Science
Cenidet-TecNM
Cuernavaca, Mexico

Dr. Juan Gabriel González Serna
Computer Science
Cenidet-TecNM
Cuernavaca, Mexico

José Luis Molina Salgado
Computer Science
Cenidet-TecNM
Cuernavaca, Mexico

Melisa Hernández Salinas
Computer Science
Cenidet-TecNM
Cuernavaca, Mexico

***Abstract*—Disability is part of human condition; it discriminates people who have this complication. The present work was carried out due to this and an experience in our research center. A prototype was designed and build that allows eye signals to be sent to a mobile device, where through a computer system, it was possible to generate an appropriate dialogue mechanism to respond to this challenge. The results allow us to open up an area of opportunity for a contribution in the inclusion of people with disabilities.**

Keywords—Communication; system; disabilities; device; oral

I. Introduction

Disability is a part of human condition: almost all people suffer some sort of passing or permanent disability at some point in their life, and those who reach senility will experience growing functioning difficulties in their organism, which in many cases causes contact loss with their familiar environment, just as in the case of young people, the critical mass is no longer used due to the fact that they have no way of communicating their knowledge.

Information from the World Health Organization in a 2010 report estimates that over one billion people live with some form of disability. According to the World Health Survey, about 785 million people, (15.6%), aged 15 and over live with a disability. It shows that, out that of the estimated total of people with disabilities, 110 million, (2.2%), have very significant functioning difficulties [1].

On the other hand, the prevalence of disability in Mexico in 2014 was 6%, according to [2], (National Survey of Demographic Dynamics 2014), information. This means that 7.1 million of the country´s inhabitants cannot or find it very difficult to do any of the evaluated activities. Reported disabilities: concentrate 42.4% (walk, walk up or down using their legs and seeing, even when wearing glasses); learning, remembering or concentrating, listening and moving or using arms or hands, together total 36.4%, while bathing, dressing, eating, talking or communicating, add up to 21.2% [3].

It's important to mention that during the 2014-2016 period, a student with oral communication problems attended his master's degree program at CENIDET - TecNM, (National Centre for Research and Technological Development - National Technological of Mexico), experimenting with his own disability during his research of Master's Thesis.

II. Related Works

Some computer systems, that help people with speech problems to communicate with the people in their environment, were checked. These are: 1) **Verbo** [4]. It is a software that can be installed in computers with Windows or Android operating systems and can be adapted to different pushbutton devices such as special keyboards, keypads, and eyepieces among others. The user constructs the phrase he/she wishes to communicate using pictograms. Another similar system is 2) **IRISBOND** [5]. That can be used by people suffering from ALS (atherosclerosis), spinal cord injury, paraplegia or other conditions, thanks to the implementation of an ocular tracking technology with which the user can manipulate the different systems installed on Windows such as: Facebook, WhatsApp, Microsoft Word, etc., it also incorporates software that allows sentence building through a virtual keyboard. 3) The third option is **AraBoard** [6]. This allows the creation, edition and use of communication boards for different devices (computers, smartphones or tablets), as well as different operating systems, in this system, users with speech problems structure their messages selecting pictograms. 4) **Eyecan** [7]. The project was introduced as a mouse that is controlled by sight and together with a virtual keyboard quadriplegic users can write messages to communicate. 5) **Alternative communication system for people with cerebral paralysis who can read and write with the support of an Android mobile device** [8]. It proposes the use of an Arduino made button and software that installs on a mobile device running Android, which uses a virtual keyboard where the user selects one by one the letters or words that make up the phrase that he wants to express one by one to ease letter selection, a swipe on the keyboard, first vertical and then horizontal, is made, stops are indicated via a button that adapts to the user´s mouth and is activated by means of oral muscle movement. 6) Lastly, **alternative and augmentative communication system for people with phonetic problems, with support of an Android mobile device** [9] and 7) **SAAC - Droid, a tool to help communication** [10]. They are systems that are installed on Android devices and use touchscreens. The first structure dialogues through pictogram selection, while the second uses a virtual keyboard. Users of these systems must have mobility in upper limbs that allows device use. Our alternative communication proposal consists of two parts: development of a non-invasive device and a computer system.

III. Device Development

To solve the problem in terms of communication, a methodology was designed, (Fig. 1), which has five activities that range from a current solution search to the implementation of a functional device.

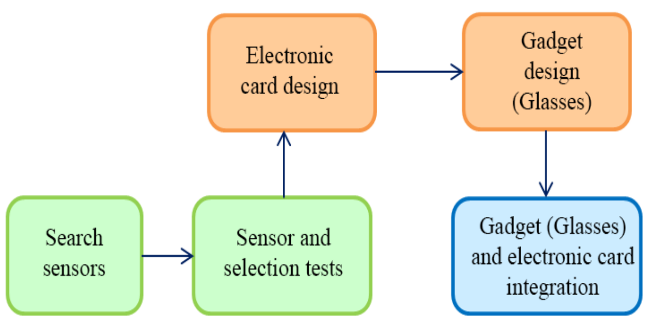

Fig. 1. Methodology.

A. Sensor Search

In the search for sensors, it was determined that the most adapted option to the solution of our problem were the reflexive optical sensors, due to the fact that people with motor disabilities have limited movements in their body parts, this is, that they have the ability to perform certain hand, finger, head and mainly eye movements. So, we focused our work on this last movement.

Considering this type of sensor, we found that the most relevant ones are the following:

1) CNY70

The CNY70 is a short-range infrared sensor based on a light emitter and a receiver, both pointing in the same direction, whose operation is based on object reflection capacity and beam detection reflected by the receiver [11].

2) IR Sharp Sensors

An Infrared sensors family for object detection offers distance information according to the range in which it receives signals, specifically in the case of the GP2D02 and GP2D12 models. These sensors work through light triangulation, which bounces off an object and according to the distance of that object, the angle tends to differ [12].

3) QRD1114

It is an optical sensor composed of an infrared diode and a phototransistor, which is responsible for detecting infrared light reflection. In general, its use achieves light change detection in black and white colors; its measurement range is between 0.5 to 1 centimeters [13].

4) TSOP4838

It is an infrared sensor used to receive infrared signals from remote controls; they are normally used in home appliances. The sensor has an amplifier circuit and a 38 Khz oscillator inside, which allows signal reception even in the presence of intense light sources [14].

5) Diode Emitter and Phototransistor

The IR LED (emitter diode) is responsible for emitting a sort of electromagnetic radiation better known as infrared light. The phototransistor differs from a common transistor because its base has been replaced by a photosensitive crystal that regulates the flow of collector-emitter current according to the light shed on it [15].

6) TCRT5000 and TCRT5000L

The TCRT5000 and TCRT5000L are reflective sensors that include an infrared emitter and a phototransistor in a lead pack that blocks visible light. The package includes two mounting clips [16].

B. Sensor Selection

So as to select the right sensor for our solution we considered the following points:

- Size: Size was considered because the sensor will be used for eye blinking detection without obstructing the user's vision.
- Distance detection: This variable was taken into account, since the sensor must detect eye blinking, thus, it must be at a certain distance from the eyewear lens to the user's eye.
- Operational voltage: an adequate voltage was taken into account due to the characteristics of device operation and the energy expenditure it represents.
- Response time: It was considered because response speed is required to be as fast as possible.

From these characteristics, the following comparative table was obtained (Table 1), where each of the features are analyzed and from which the best suited sensor for the job was selected.

TABLE I. COMPARATIVE TABLE (SENSORS)

Sensor	**Characteristics**			
	Dimensions	***Range detection***	***Operation Voltage***	***Response time***
CNY70	7 x 7 x 6 mm	< .5 mm	5V	
GP2D02	37x14x14.4mm	10 a 80 cm.	4.4 a 7V	70 µs
GP2D12	37x14x14.4mm	10 a 80 cm.	4.5 a 5.5V	32 µs
QRD1114	6.1x4.39x4.65 mm	0.050” (1.27 mm)	5V	10 µs, 50 µs
TSOP4838	3 cm x 0,5 cm	35m	3 a 6V	9 µs
Emitting Diode and Phototransistor	5 y 3 mm	-----	3 a 5V	------
TCRT5000L	10.2 x 5.8 x 7 mm	2.5 mm	5V	10 µs

C. Electronic Card Design

For the electronic card design, two PCB (Printed Circuit Board) design software were used, these are:

1) PCB Wizard

It is an educational area designed program, which allows electronic circuit schematics creation and thus easily obtain one or two-sided printed circuit designs [17].

2) Fritzing

It was created under the Processing and Arduino principles, allowing designers to document their prototypes based on Arduino and create printed circuit diagrams for later manufacture.

It is an open source software and has libraries with the majority of components that include the Arduino ones, connection boards, LED, motors, displays, among others [18].

D. Gadget Design (Glasses)

Within this stage a previous analysis was carried out on some commercial glasses type devices to take into account size, weight, ergonomics and materials used in them.

The analyzed devices are the following:

- Google Glass [19].
- Epson Moverio bt-200 [20].
- Wink Glasses mod. 2013 [21].
- Glassup [22].
- Vuzix Smarth Glasses [23].

For gadget modeling, AutoCAD software, which provides tools to develop 3D models, was used.

Development steps were as follows:

- A first pencil sketch was designed (Fig. 2).
- The first sketch was modeled in AutoCAD (Fig. 3).
- The 3D model was printed.
- The reflective optical sensors were placed on the lens of the glasses.
- The design was modified due to the tests performed with the sensors (Fig. 4).
- A final prototype was established (Fig. 5).

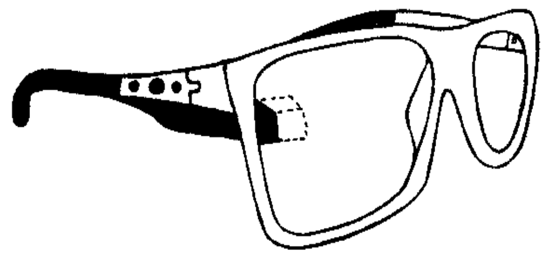

Fig. 2. First pencil sketch glasses.

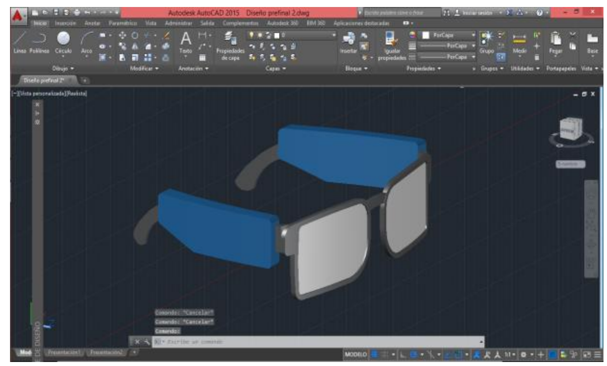

Fig. 3. First sketch in AutoCAD.

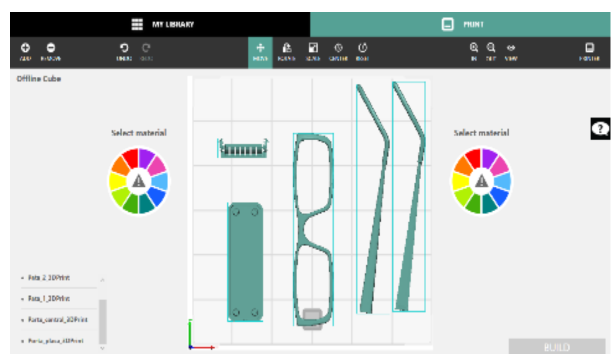

Fig. 4. Second design seen from the Cube Print platform ready for printing.

Fig. 5. Final prototype.

E. Electronic Card and Gadget Integration

Once the lens was printed, the electronic card was inserted inside the plate holder, which is placed on the right side of the glasses and the corresponding connections to the battery holder, placed on the left side, were made, so as to finally have a functional prototype which integrates all the parts to fulfill their integral function.

To obtain better sensor readings, these must have a calibration function, so that the detected information received from the sensors is adapted to the characteristics of the user. For this, tests were carried out to verify reading efficiency in sunlight, white LED and dark environments (Table 2).

Once the gadget is duly integrated, data detected by the sensor is sent wirelessly to a system where it is converted to letters, so that later on the user can form words and thus establish communication with people in their environment.

Environment 1 = Environment with sunlight

Environment 2 = White led light

Environment 3 = Darkness

TABLE II. EXPOSURE OF SENSORS TO DIFFERENT ENVIRONMENTS

User	**Environment 1**	**Environment 2**	**Environment 3**
1	10/10	10/10	10/10
2	10/10	10/10	10/10
3	10/10	10/10	10/10
4	7/10	7/10	7/10
5	10/10	10/10	10/10
6	10/10	10/10	10/10
7	10/10	10/10	10/10
8	10/10	10/10	10/10
9	10/10	10/10	10/10
10	10/10	10/10	10/10
Percentage	**97%**	**97%**	**97%**

It should be noted that for these trials, tests were made on 10 people aged between 22 to 28, who were not necessarily disabled, and each user was told to blink 10 times to determine the amount of blinks detected by the sensors, and based on this, know if the sensor position calibration in the lens of the gadget was correct.

IV. APPLICATION (SOFTWARE)

A computer system was developed to use the device with a mobile, it is able to communicate wirelessly with the device in charge of sending the user's signals, allows obtained information gathering based on user blinking by executing actions such as: write a letter, predict a word, formulate sentences and interpret in a sonorous way what the user writes. The developed system consists of:

- Wireless communication module.
- Data transformation algorithm.
- Dictionaries.
- Interpretation algorithm.
- Matching algorithm.
- Audio playback module.

A. Wireless Communication Module

The system makes use of the computer device's wireless technologies on which it is installed; this system is compatible with Wi-Fi or Bluetooth communication.

"Bluetooth® is a low-power wireless connectivity technology used to stream audio, transfer data and broadcast information between devices." [24].

"Wi-Fi is a wireless networking protocol that allows devices to communicate without Internet cables. It is technically an industry term that represents the type of wireless local area network (LAN) protocol based on the 802.11 IEEE network standards." [25].

Technologies such as Bluetooth and Wi-Fi are ideal for a system that requires communication at a distance no greater than 10 meters; in addition, these technologies are quite common in everyday computing devices.

The system is programmed to send and receive information from the signal detection device, so that the data can be obtained in real time and does not depend on the complementary use of some other type of technology. Fig. 6 shows a schematic of the module composition.

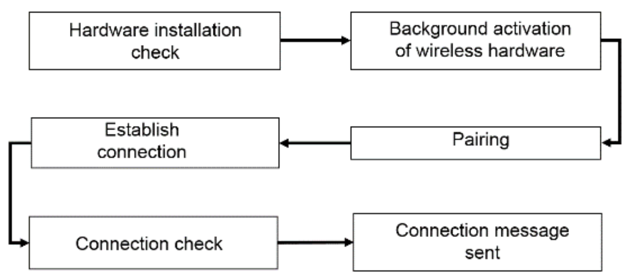

Fig. 6. Connection module.

B. Data Transformation Algorithm

The system has a module responsible for transforming data that is received from the device, this data is entered into different variables to be processed and know what instructions the user wants executed. The module is in charge of identifying the instruction taking into account the time that elapses between the sending of the signals coming from the device and where the obtained signals take values from A and B.

The listed instructions are executed according to data reception time, where: Instruction 1 (i1), Instruction 2 (i2) ... Instruction n (in), are established by knowing the time (t) in milliseconds (ms) that exists between receiving a value A (t1) with a value B (t2).

The instructions are executed if and only if:

1) i1

$$100 \text{ ms} < \text{t1} - \text{t2} <= 1000 \text{ ms}$$

2) i2

$$1000\, ms < t1 - t2 <= 2000\, ms$$

3) i3

$$2000 \text{ ms} < \text{t1} - \text{t2} <= 3000 \text{ ms}$$

4) in

$$\text{n ms} < \text{t1} - \text{t2} <= \text{n ms}$$

The following shows the work scheme of the data transformation algorithm (Fig. 7).

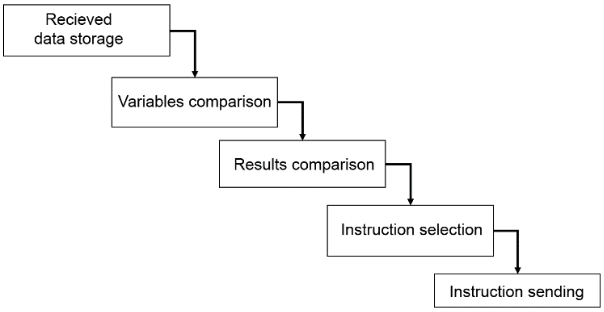

Fig. 7. Data transformation algorithm.

C. Dictionaries

The system has three types of dictionaries, General, Temporal and Custom, which are used for storing relevant information, (words), that will be used by the user, making their writing easier (Fig. 8).

"A Data Dictionary is a collection of names, definitions, and attributes about data elements that are being used or captured in a database, information system, or part of a research project. It describes the meanings and purposes of data elements within the context of a project, and provides guidance on interpretation, accepted meanings and representation [26].

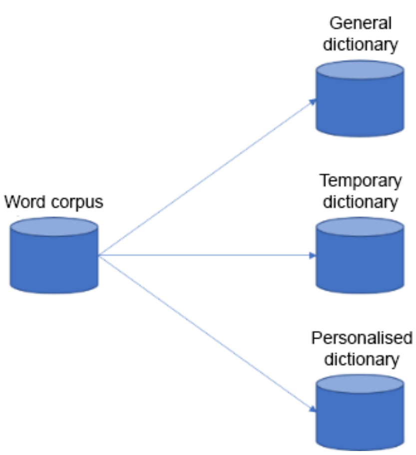

Fig. 8. Corpus and dictionaries.

At first the general dictionary was composed of a corpus of the most used words in Spanish and is available on the official website of the Royal Spanish Academy [27], this information is the basis for custom and temporary dictionary creation, (Fig. 9). Later the English language was added, and it is intended to incorporate as many languages as necessary.

D. Interpretation Algorithm

"Morse code is a code or communication system that allows telegraphic communication through the transmission of electrical impulses of various lengths or by visual means, such as light, sound or mechanics. This code consists of a series of points; stripes and spaces, which when combined together can form words, numbers and other symbols" [28].

Within the system, Morse code allows anyone in the world to make use of it, since implemented Morse code is the international version; it has a great variety of numbers, symbols and letters that adapt to most languages.

According to instructions received from the data transformation algorithm, character writing can be established in Morse code, considering points and lines for word and sentence generation. The international Morse code also allows the user to write with a single alphabet in different languages. Fig. 9 shows the code used in the system.

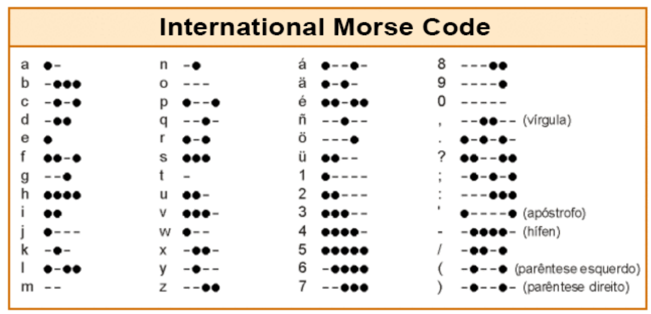

Fig. 9. Morse code (Daisy, 2017).

E. Matching Algorithm

This algorithm is in charge of using and manipulating different dictionaries, when an alphabetic character written by the user is presented, the algorithm makes an input data selection to find one or more word matches that can be used by the user, if the user wants to write a word of two or more characters, the algorithm receives as input a single character that serves as an indicator to perform the search for a suggestion.

The word matches can be defined as:

- C = Initial character
- P = Word of the dictionary
- Pc = Complement of the word = P – C

Thus,

- Co = Coincidence = C + Pc

Subsequently a selection of suggestions considered as foremost is made, based on all coincidences found in dictionaries and evaluating the nominal frequency of the corpus of words, to obtain the words with greater use probability in the selected language. Fig. 10 is a graphical representation of the matching algorithm operation.

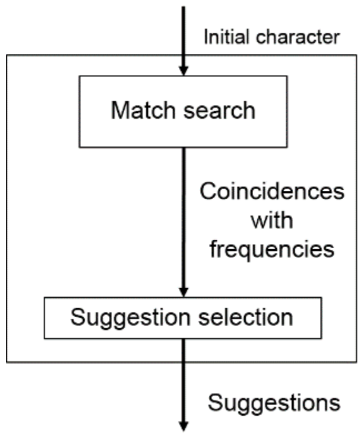

Fig. 10. Matching algorithm.

F. Audio Playback Module

To reproduce in a sonorous way the texts elaborated or prepared by the user, the system has a text to voice conversion module, to achieve this, it uses tools provided by Google. This module is responsible for storing the textual information in an **O** variable and passing it as a parameter to a process that executes the audio playback tools so that the user and the people around him can listen to the previously written messages.

V. TESTS

For testing we relied on the "**Con Nosotros**" foundation, which specializes in basic education of people with cerebral paralysis. Test reactions were applied to enrolled students at the institution.

A test plan was built to validate the system; this consisted of three phases where an evaluation of each phase was carried out.

The first phase aimed to enable the user to identify the precise interpretation time of each selected option. They were asked to practice at least ten actions for each of the available options. The results were evaluated and if at least 70% of successful values were obtained, the second phase would proceed; Table 3 shows the results obtained.

TABLE III. SELECTED OPTIONS TABLE

User	**Point**	**Dash**	**Selection mark**
1	10/10	10/10	10/10
2	10/10	10/10	10/10
3	9/10	8/10	7/10
Average	9.6/10	9.3/10	9/10
Percentage	**96.6%**	**93.3%**	**90%**

As can be seen in Table 3, users 1 and 2 results were 100%, unlike user 3, since the latter suffered slight involuntary head movements, which prevented him from maintaining his head position in a single place, as a result of this, the inclination of his head created a shadow that didn't allow continuous light illumination in the controlled environment, that is why the signals obtained by the sensors placed in the gadget didn't have correct eye blinking detection.

The second phase aimed to enable the user to select a button in the application interface. The test in this phase consisted in asking the user to select three buttons that had been previously determined, ten times, these were located in different places on the interface, they had to make seven attempts at pressing each button correctly so that this test could be successfully completed. The results of this test can be seen in Table 4.

TABLE IV. SECOND PHASE RESULTS

User	**Button "A"**	**Button "R"**	**Button "Z"**
1	10/10	10/10	10/10
2	10/10	10/10	10/10
3	7/10	9/10	9/10
Average	9/10	9.66/10	9.66/10
Percentage	**90%**	**96.6%**	**96.6%**

Lastly, in the third phase, a full use of the application was made. The test consisted in asking the user to write longer phrases, which were made up of more than three words and would then be reproduced using a speech synthesizer; the phrases that were used for the tests are shown in Table 5:

TABLE V. PHRASES

No.	Phrase
1	Hello, good day
2	My name is "User name"
3	My favorite food is "User's Favorite Food"

Test results were:

As can be seen in Table 6, users 1 and 2 correctly completed any of the 3 sentences, while user 3, due to the involuntary movements of his head, failed to coordinate the movement of his eyes to select the desired button.

As for the average writing times, writing each sentence in ten tries was considered, taking the average time of the first five attempts and the last five attempts. Tables 7 and 8 shows the results obtained.

TABLE VI. COMPLETED PHRASES

User	**Phrase 1**	**Phrase 2**	**Phrase 3**
1	10/10	10/10	10/10
2	10/10	10/10	10/10
3	10/10	8/10	7/10
Average	10/10	9.3/10	9/10
Percentage	**100%**	**93.3%**	**90%**

TABLE VII. FIRST FIVE ATTEMPTS

User	**Elapsed time in phrase 1**	**Elapsed time in phrase 2**	**Elapsed time in phrase 3**
1	6.46	8.09	8.19
2	8.55	9.33	9.56
3	10.57	11.37	12.51
Average	**8.49**	**9.46**	**10.22**

TABLE VIII. LAST FIVE ATTEMPTS

User	Elapsed time in phrase 1	Elapsed time in phrase 2	Elapsed time in phrase 3
1	1.21	2.12	2.1
2	2.07	3.04	4.03
3	2.27	6.24	10.07
Average	**2.07**	**3.43**	**5.26**

A reduction of more than 6 minutes for sentences 1 and 2 can be seen, a little more than 4 minutes in sentence 3.

VI. CONCLUSIONS

During this project's making, an effective proposal was sought for phrase and sentence writing, it was considered that one way is to obtain input as binary data, so taking into account the availability of Morse code, it was decided to implement a methodology in where its only necessary to select the desired object on the screen, from the first of the row and scroll the objects until you reach the desired element, this way writing time was reduced in the application.

When testing in controlled environments, with users suffering from cerebral paralysis, it was observed that this system is useful only for users who, besides having full control over their blinking, do not present involuntary movements that affect excessively their head position, since when tilting the head down, the sensors enter the shadow generated as a result of this inclination, giving an incorrect eye blinking reading due to this change of light.

However, according to the opinion of the three users the application is simple to use and easy to memorize when looking for a desired letter.

There is an area of improvement in both the device and the computer system and work will continue. On the other hand, there are some limitations to carrying out more tests, due to the fact that because it is often difficult for institutions that tend to this stratum of people to have enough time to apply tests.

ACKNOWLEDGEMENT

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FFD Variants for Virtual Machine Placement in Cloud Computing Data Centers

Aneeba Khalil Soomro, Mohammad Arshad Shaikh, Hameedullah Kazi
Department of Computer Science
ISRA University
Hyderabad, Pakistan

***Abstract*—Virtualization technology is used to efficiently utilize the resources of a Cloud datacenter by running multiple virtual machines (VMs) on a single physical machine (PM) as if each VM is a standalone PM. Efficient placement/consolidation of VMs into PMs can reduce number of active PMs which consequently reduces resource wastage and power consumption. Therefore, VM placement algorithms need to be optimized to reduce the number of PMs required for VM Placements. In this paper, two heuristic based Vector Bin Packing algorithms called FFDmean and FFDmedian are proposed for VM placement. These algorithms use First Fit Decreasing (FFD) technique. FFD preprocesses VMs by sorting all VMs in descending order of their sizes. Since a VM is multidimensional therefore, it is difficult to decide on its size. For this, FFDmean and FFDmedian use measures of central tendency, i.e. mean and median as heuristics, respectively, in order to estimate the size of a VM. The goal of these algorithms is to utilize the PM resources efficiently so that the number of required PMs for accommodation of all VMs can be reduced. CloudSim toolkit is used to carry out the cloud simulation and experiments. Algorithms are compared over three metrics, i.e. hosts used, power consumption and resource utilization efficiency. The results reveal that FFDmean and FFDmedian remarkably outperformed two existing algorithms called Dot-Product and L2 in all three metrics when PM resources were limited.**

Keywords*—Cloud computing; virtual machine placement; virtualization; first fit decreasing; first fit decreasing (FFD)

I. Introduction

Cloud computing is an internet based business model of computation for outsourcing computing resources such as processing power, networks, servers, storage, applications, and services [1]. NIST (National Institute of Standards and Technology) published their 16th and final definition of cloud computing, which is.

"Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g. networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction" [1].

Cloud computing provides a lot of opportunities for the IT industry. It is a rapidly enhancing and developing paradigm. The modern computational power has allowed it to become a utility that provides services to customers on a pay-as-you-go model i.e. the customers are required to pay only when they use the service. Hence, it is considered to become 5th utility [2] of our lives after other four utilities such as electricity, water, gas and telephony.

In cloud computing everything that is provided is a service. The services are available on-demand from anywhere in the world through internet. A cloud service provider provides services to its customers in three basic service models, which are:

1) Software-as-a-Service (SaaS): SaaS is software provided as a service. The software (application) is provided on demand which is built over an infrastructure and a platform. The software provided is a web application, accessible through a browser [3]. SalesForce, BaseCamp, GoToMeeting and NETSUITE are some examples of SaaS.

2) Platform-as-a-Service (PaaS): PaaS is a complete platform provided as a service to developers, which consists of all the required systems and the developing environment with underlying infrastructure. The end users (developers) of this service are allowed to develop their own software by testing, deploying and then hosting their custom web based applications [3]. Generally PaaS is a middleware (like OS) that allows communication between hardware and application [4]. Google APP Engine and IBM bluemix are some examples of PaaS.

3) Infrastructure-as-a-Service (IaaS): IaaS is a complete infrastructure provided as a Service. It provides Computing power with high level of adjustability as it allows the developers to create their own infrastructure like virtualization, etc. [3]. The customer is allowed to build their own platform and software over it. Amzaon EC2 and IBM Cloud are some examples of IaaS.

These services are highly scalable i.e. they may be increased or decreased according to the current demand of customers. The cloud customer does not need to worry about management and provisioning of resources when the demand rises or decreases. This is all done at the cloud providers' side. This relaxes customers from the hassle of managing, updating, over and under provisioning of resource (The customers and the service providers agree upon a contract called Service Level Agreements (SLAs) [27] to ensure Quality of Service (QoS).

The cloud Infrastructure is based on huge datacenter(s) comprised of millions of physical machines (PMs). These next-generation datacenters are so powerful that millions of customers can be served. Every end user is assigned a dedicated virtual machine (VM) which eventually runs on a PM residing in a Cloud datacenter. This is accomplished by using virtualization technology which helps in sharing PM resources to multiple users by running multiple VMs on a single PM as if each VM is a standalone PM [5]. Since these PMs are hosts for VMs, PMs are also called as hosts.

A lot of electrical power is wasted due to inefficient utilization of datacenter's physical resources which results in high operational costs. About 70% of total data center's power is consumed by PMs [6]. The principal approach to power saving in cloud computing is to cut the operational costs of datacenters by efficiently utilizing the resources of a PM, in order to minimize the number of PMs in use and idle/inactive PMs are turned off or to low power mode [7]. Hence power efficient cloud computing [26] is an active research area and is often termed as Green Cloud Computing.

The VM placement (VMP) is a process of allocating VMs into PMs. A VM Placement algorithm is responsible to place/consolidate VMs into PMs. Efficient placement of VMs can reduce the number of PMs required for their accommodation, consequently increasing utilization of PM's resources and reducing power consumption. Therefore, there is a continuous need to design efficient algorithms for VMP so that VMs are packed in minimum possible PMs and resource utilization efficiency is increased by increasing utilization of each resource in a PM.

In this work two Vector Bin Packing (VBP) algorithms named as FFDmean and FFDmedian are proposed. These algorithms are essentially First Fit Decreasing (FFD) variants which are supposed to increase PM utilization to reduce number of PMs required and in turn reduce power consumption.

The remaining paper is structured as follows: Section II discusses the related work to this research. Section III formulates VMP problem as VBP problem. Section IV discusses the proposed algorithms. Section V describes the system model. Section VI explains the experimental setup. Section VII presents the results. Section VIII discusses the results. Section IX concludes this research and Section X presents the future recommendations.

II. Related Work

Cloud computing is a rapidly growing paradigm of computer science. A lot of academic and industrial research [24], [25] has been conducted in this field to enhance the quality of cloud. As our work is specific to VMP, in this section some of the work related to VMP in cloud computing is reviewed.

A. Power Aware VMP Approaches

Power conservation is a very important challenge in Cloud computing. In this section some of the VMP algorithms/policies that opt for power conservation are discussed.

1) Cutting back power usage and co_2 footprint by ECE algorithm: To become highly available, cloud data centers maintain different power sources. Mostly, these sources are not renewable and use carbon fuels to run, eventually leading to increased carbon footprint (cf) of environment which is injurious to our environment and health. The cf rate of these power sources is an important consideration, since data centers utilize electricity provided by these sources to run PMs and eventually VMs.

Khosravi et al. in [8] proposed ECE algorithm for VMP to minimize power consumption and cf. ECE integrates two parameters i.e. Power Usage Effectiveness (PUE) and cf. It aims to place a VM in to a PM so that the power consumption, cf and PUE of the PM, its datacenter and cluster is minimized. Initially, when a VM request is received, ECE sorts all the clusters by their PUExcf values in ascending order. After that for each PM in a cluster the change in power consumption (ΔP) after that VM's placement is calculated. These PMs are then sorted in ascending order of their ΔP. A suitable PM which has minimum ΔP after placement is selected. If a suitable PM is not found for the VM, algorithm tries the next cluster. The ECE algorithm decreased cf and saved power compared to many existing algorithms.

2) Power saving by demand forecasting: As cloud computing has an on-demand resource provisioning method; resource (de)allocation is dynamic. The service provider needs switched on PMs in spare to deal with dynamic resource demands. These idle PMs until they get some work waste a lot of power. On the other hand switching them on/off on demand also wastes power and takes 2-3 minutes to restart. One way to solve this issue is to standby the inactive PMs. It takes less time to restart and also consume lesser power compared to completely switching them off. If the future resource demands are estimated before time then according to the estimate some PMs could be set on standby while others shutdown to save power.

Cao et al., in [9] proposed a power efficient approach to solve VMP problem by forecasting the demand for VMs. The VMP is carried out in three steps. Initially demand forecasting is done by using Holt-Winter's exponential smoothing method assuming that in cloud computing a particular user's demands are identical and a particular demand succeeds a seasonal pattern. Next, a modification of multi-dimensional knapsack algorithm is used to allocate VMs to hosts; considering hosts as knapsacks and VMs as items with two types of costs i-e memory and cores. Finally a self-Optimizing module is used to update the forecasting parameter values in the demand forecasting model and mining the appropriate forecast periods by Hill Climbing method. The experiment result showed that proposed algorithm with forecast saves up to 60% power.

3) Power saving by decentralized VM migration technique for fault-tolerant load balancing: Mostly, centralized approaches are used for resource management in cloud computing. Management becomes easy with these approaches however they are not fault tolerant. If the centralized resource manager crashes, all of the system crashes and becomes unmanaged.

Wang et al. in [10] proposed a decentralized VM migration technique for resource management instead of using a central resource manager, for fault-tolerance and to efficiently balance load across the data center and save power. In this approach each PM sends its load information maintained in a load vector, to every other PM in the data center(s), thus all active PMs have each other's load information. The proposed DVM algorithm uses lower and upper thresholds to judge the over and underutilization of a PM's CPU respectively. VMs are migrated from PM's with over utilized CPU to avoid SLA violations. In an underutilized PM, all VMs are migrated to some other PM with minimum increment in utilization after addition of migrating VM and the PM is turned off/sleep for power conservation. DVM showed balanced resource utilization and saved up to 20% power compared to static and round robin algorithms.

4) Power saving by euclidean distance based algorithm: Srikantaiah et al. in [11] proposed a power aware multi dimensional bin-packing algorithm that uses a euclidean distance based heuristic for VMP. The algorithm considers two dimensions i.e. CPU and disk. It first finds out an optimal point where combination of CPU and disk utilization gives minimum power usage per transaction. Next, when it receives application (VM) requests it uses the euclidean distance heuristic which calculates euclidean distance of the utilization of each PM after allocation of the requested VM to the optimal point calculated in first step. The PM that has maximum euclidean distance of all is selected for VMP. Results showed that more power is saved as performance degradation tolerance is increased. At 20% tolerance the proposed algorithm used only 5.4% more power than optimal algorithm.

5) Power saving by live VM migration using vector based repacking: Consuegra et al. in [12] proposed a vector repacking algorithm called replicas to minimize operational costs of a datacenter, that include power and migration cost. This algorithm places copies of each item/VM on different PMs that are selected by replica allocation algorithm. Among these copies only one copy is considered to be active and the operations are executed on it. When a VM has an increase in demand and cannot fit anymore in the current PM where it resides, then a PM is selected by the help of active replica selection algorithm. The copy in the newly selected PM is activated, the newly activated copy is synchronized with the previous copy to update if there are any changes and the previous copy is sent to inactive mode. By using replicas algorithm migration cost is reduced or even eliminated.

6) Consolidating complementary VMs with spatial/temporal-awareness in cloud datacenters: Chen et al., in [13] proposed a spatial/temporal aware VBP algorithm for initial VMP. The algorithm forecasts resource usage patterns of VMs and packs together complementary VMs with spatial/temporal knowledge. This algorithm considers balanced utilization of CPU and memory of a PM. For e.g. a high CPU-intensive and low memory-intensive VM and a low CPU-intensive and high memory-intensive VM can be packed together to give a balanced utilization of PM resources. These types of VMs are complimentary VMs i.e. VMs for which overall requirement of every resource dimension (in the spatial space) almost arrives at their PM's capacity throughout VM lifetime phase (in the temporal space). The results show that the proposed techniques helped in utilization of PM's resources, reduction in VM migrations and active PMs in use alongwith maintaining SLAs.

B. Vector Bin Packing Algorithms for VMP

In cloud computing the VM resource demands are multi-dimensional. To solve the multidimensional VMP problem one of the solutions is to use a variant of bin packing called Vector Bin Packing (VBP) is used. Unlike the classic bin packing it considers the items and bins as multi-dimensional vectors.

1) FFD variants for VBP: VBP can be solved by classic FFD heuristic. In FFD, items are first sorted by decreasing order of their sizes and then placed in the first bin (container) they fit into. Since in VBP the items are considered as multi-dimensional, it is difficult to decide the size of an item. For this, many FFD variants have been put forward which use some heuristic to estimate the size of a multidimensional item.

Maruyama et al. in [14] proposed a generalized VBP algorithm for FFD and best fit decreasing (BFD) techniques where BFD chooses the best bin in which an item can fit into. The algorithm considers many heuristics to estimate the size of a multi-dimensional item. The heuristics include taking product of all dimensions, sum of average and standard deviation of all dimensions and different versions of sum of all dimensions. Among these they found taking sum of dimensions and sum of average and standard deviation, far better than taking product. Kou and Markowsky in [15] proposed multidimensional bin packing algorithms. Three heuristics were used to calculate the size of items for FFD and BFD. Heuristics used for deciding the size were lexicographical (Lex), maximum component (Max) and sum of components. In Lex an item a>b if a equals b or first component of a-b is positive. In Max a>b if maximum component of a is greater than that of b. In sum of components a>b iff sum of all components of a is greater than that of b.

Spieksma in [16] proposed FFD heuristic algorithm which sorts items by assigning priorities and a branch and bound algorithm for 2-dimensional (2d) VBP. Han et al., in [17] proposed heuristics and exact algorithms for 2d VBP for heterogeneous bins. Caprara and Toth in [18] also studied the 2d case of VBP in detail. They proposed enhanced lower bounding methods, heuristics, and exact algorithms for this problem. Stillwell et al. in [19] proposed some VBP algorithms for resource allocation in virtualized shared hosting platforms. To sort items for FFD and BFD they used heuristics such as Sum, Max and Lex from [15]. They also proposed choose pack and permutation pack algorithms, greedy algorithms, a genetic algorithm and relaxed linear programming solution. From all these, the algorithms which used Sum as a heuristic performed well. Panigrahy et al. in [20] proposed two FFD variants called Dot-Product (DP) and L2 which use dot product and L2 norm techniques, respectively as heuristics to estimate the size of a VM.

Measures of central tendency such as mean and median are used to calculate a particular value from a dataset which identifies the central point of that dataset. This technique can be used to estimate the size of a multi-dimensional VM. As far as related work is reviewed for this research, FFD variants that use these measures for VMP in cloud computing environment are not found. Therefore, in this work two new VBP algorithms called FFDmean and FFDmedian for VMP in cloud computing environment are proposed, which are essentially FFD variants. The algorithms use mean and median respectively as heuristics to estimate the size of a VM.

III. Problem Formulation

1) VBP problem: Vector Bin packing (VBP) problem is a variant of bin packing problem. It is NP-hard which means that it cannot be solved in polynomial time however approximation algorithms are proposed for this problem. The problem is all same as bin packing problem except the items here are not one dimensional but d-dimensional vectors where d≥2.

The resource demand of an item is represented by demand vector $\vec{D}$ and the bin capacity is represented by resource vector $\vec{R}$. Both vectors are d-dimensional where d≥2 and are represented in (1) and (2), respectively, here *i* is item's demand and *c* is the bin's capacity in a particular dimension.

$$\vec{D} = \{i_1, i_2 \ldots i_d\} \quad (1)$$

$$\vec{R} = \{c_1, c_2 \ldots c_d\} \quad (2)$$

In VBP, there is B number of bins each with a resource vector $\vec{R}$ and I number of items each with a demand vector $\vec{D}$. The problem is to place all items in minimum number of bins, such that in each bin *b*, the sum of demands in each dimension of all accommodated items does not exceed the bin capacity in each corresponding dimension.

2) VMP problem: VM Placement (VMP) problem is a NP-hard problem. The VMP problem receives a set *V* of VMs, each with d-dimensional resource demands and a Set *P* of PMs, each with d-dimensional resource capacity. The problem is to place all VMs in minimum number of PMs, such that in each PM the sum of demands in each dimension of all VMs does not exceed the PM capacity in each corresponding dimension.

3) VMP problem formulation as VBP problem: Since VMP problem is multi-dimensional, it is difficult to formulate it as general bin packing problem. VMP Problem can be transformed into a VBP problem by considering VMs as items with d-dimensional demand vector $\vec{D}$ and PMs as bins with d-dimensional resource vector $\vec{R}$. In this work $\vec{D}$ in (3) for a VM v has four-dimensions which are CPU mips, ram, bandwidth (bw) and Storage (strg). $\vec{R}$ in (4) for PM p which is used as a host for VMs also has the same dimensions.

$$\vec{D} = (v_{mips}, v_{ram}, v_{bw}, v_{strg}) \quad (3)$$

$$\vec{R} = (p_{mips}, p_{ram}, p_{bw}, p_{strg}) \quad (4)$$

IV. Proposed Algorithms

FFDmean and FFDmedian are two new VBP algorithms proposed for VMP in cloud computing environment. The algorithms use classic FFD heuristic.

FFD is a simple heuristic approach to solve bin packing problem, which receives set of items and bins. Since FFD is used here for VMP, items are considered as VMs and bins as PMs/hosts. In FFD, VMs are first sorted in descending order of their sizes. After that starting from the largest VM, each VM is placed in the first available PM they fit into. The process continues until all VMs are placed.

The first requirement of FFD heuristic is to sort all the VMs into descending order of their sizes; however in this case where a VM is four-dimensional vector, it is difficult to decide which dimension should be selected as size of a VM. Therefore, a particular value/number is required in order to sort VMs. For this, measures of central tendency such as mean and median can be used to calculate a particular value from demand vector $\vec{D}$ of a VM. This value identifies the central point of the vector $\vec{D}$ and is the estimated size of a VM.

A. FFDmean and FFDmedian

FFDmean and FFDmedian use mean and median respectively to estimate the size of a multi-dimensional VM. The algorithms work in three steps, i.e. Normalization, size estimation and sorting and placement. Step 1 and Step 3 are same for both algorithms, however Step 2 is different.

1) Step 1 (Normalization): In this step, all the VMs are normalized to bring them on same scale. VMs are normalized by dividing all dimensions of a VM by their corresponding dimension in the PM as shown in (5).

$$\text{normalized\_VM} = \left(\frac{v_{mips}}{p_{mips}}, \frac{v_{ram}}{p_{ram}}, \frac{v_{bw}}{p_{bw}}, \frac{v_{strg}}{p_{strg}}\right) \quad (5)$$

2) Step 2 (Size Estimation): In this step, the size of each VM is estimated by using a Size function S. This function is different for FFDmean and FFDmedian.

a) Size function for FFDmean: For FFDmean this function calculates mean of VM dimensions in demand vector $\vec{D}$. The larger the mean the larger is the VM size. The size function S for FFDmean is presented in (6) where v represents a VM, i is a dimension and d is the total number of dimensions (1 ≤ i ≤ d) from $\vec{D}$.

$$S(v) = \frac{\sum_{i=1}^{d} v_i}{d} \quad (6)$$

b) Size function for FFDmedian: For FFDmedian this function calculates median of VM dimensions in demand vector $\vec{D}$. The larger the median the larger is the VM size. For median there are two cases. The first case is for odd number of dimensions in $\vec{D}$. In this case the middle value is taken as the median. The second case is for even number of dimensions in $\vec{D}$, which is true for this research. In this case two middle values are taken and then average of these values is calculated. The size function S for the second case is presented in (7) where v represents a VM and x and y represent two middle values in $\vec{D}$.

$$S(v) = \frac{x+y}{2} \tag{7}$$

3) Step 3 (Sorting and placement): In this step, all the VMs are sorted in decreasing order of their sizes and then placed in PMs by using FFD technique.

Bin-centric version of FFD [20] is used in which a PM is taken at a time *t*. The process continues from Step 1 to Step 3 for each PM until no VM is left for placement.

V. System Model

This work is based on the IaaS layer of cloud computing. CloudSim toolkit [21] is used to simulate the IaaS environment and the experimental setup. CloudSim is a framework for modeling and simulation of cloud computing infrastructures and services.

The system consists of one datacenter which contains 800 identical PMs. Since the cloud computing datacenters are multi-tenant i.e. VMs of different users might run on same PM, the VM instances are designed to bring the effect of different resource requirements by different users. For example, a user may demand a VM with high CPU capacity while another user may demand a VM with high memory etc. There are six types of VMs inspired by Amazon EC2 VM instances, used in our experiments. VM requirements are designed to be within PM capacities.

This work is limited to only initial VMP. This means that VMs complete their lifetime in only one PM in which they are initially placed and they are not migrated. Four algorithms are used separately for VMP. The algorithms are FFDmean, FFDmedian, Dot-Product (DP) and L2. FFDmean and FFDmedian are the proposed algorithms in this work while DP and L2 [20] are existing algorithms used for comparative analysis. DP uses dot product and L2 uses L2Norm as heuristic to estimate the size of a VM. In DP the larger the dot product between $\vec{D}$ and $\vec{R}$ the larger is a VM's size whereas in L2 the smaller the difference between $\vec{D}$ and $\vec{R}$ the larger is a VM's size.

The system receives user requests for VMs in the form of PlanetLab workload. It is a real workload of user requests (tasks/Jobs) selected by CloudSim from PlanetLab and provided by CoMon project [22].

A. PlanetLab Workload

PlanetLab is a research network spread worldwide which supports the advancement of new network services. From the start of 2003, above 1,000 researchers from industrial research labs and remarkable academic institutes have chosen PlanetLab to develop new techniques for distributed storage, peer-to-peer systems, network mapping, distributed hash tables, and query processing.

PlanetLab workload is the real workload traces from real systems. It is the data made available as a part of the CoMon project [22] which is a monitoring infrastructure for PlanetLab. This data consists of CPU utilizations of more than a 1,000 VMs from PMs (servers) situated at more than 500 places around the world. The utilizations of VMs are measured at an interval of five minutes.

To make our experiments more authentic it is important to test our algorithms with a real workload. For this we have chosen the PlanetLab Workload traces of 10 random days collected during March and April 2011, provided in CloudSim.

B. Power Model

Power consumption in an IaaS is decided by data center resources such as electric power supplies, cooling systems, CPU, memory, disk storage, network equipment, etc. According to recent research [23], among these resources CPU utilization has a linear relationship with PM's power consumption. This is because there are least amount of states that can be assigned to the voltage and frequency of a CPU and furthermore performance scaling such as DVFS (Dynamic Voltage and Frequency Scaling) is not functional to other resources that use power, for instance network devices, memory, storage, etc.

Due to the increased use of virtualization technology, state-of-the-art PMs are designed with multi-core CPUs and large quantities of other resources. Memory, network and other devices also add in the power consumption of a PM. For the reason that modeling power expenditure of current PMs is a difficult research problem, in this research genuine information on power expenditure made available by SPEC (Standard Performance Evaluation Corporation) power benchmark is used rather than making an analytical power model [23]. SPEC power model provides real power usage of PMs at different CPU usage/load levels.

VI. Experimental Setup

Three Experiments are designed to evaluate FFDmean and FFDmedian algorithms compared with DP and L2. In each experiment, there is one datacenter with 800 identical PMs of types 1, 2 and 3, respectively as shown in Table 1. The difference between the experiments is the PM type (configuration). Since the goal is to test the performance sustainability of algorithms as the resources increases under different PM types. VMs are created according to the Instances provided in Table 2.

Jobs/tasks for VMs are taken from PlanetLab Workload provided in CloudSim which is divided into 10 parts or workloads. All algorithms i.e. FFDmean, FFDmedian, DP and L2 are used separately for VMP for all PlanetLab Workloads. Therefore, we have four algorithms, 10 workloads and three experiments; we get total 120 simulations (4*10*3).

Power model made available by SPEC power benchmark for each host type is used. Power consumption of these PMs at different CPU usage/load levels is presented in Table 3.

TABLE I. PM CONFIGURATION

Physical Machine		PM Configurations				
		CPU	*Cores*	*RAM*	*Strg*	*BW*
1	HP ProLiant ML110 G5	2.66 GHZ (2660 MHZ)	2	4 GB (4096 MB)	160 GB (163840 MB)	1000 Mb/s
2	IBM System x3250 M3	3.07 GHz (3067 MHz)	4	8 GB (8192 MB)	160 GB (163840 MB)	1000 Mb/s
3	IBM System x3550 M3	2.93 GHz (2933 MHz)	6	12 GB (12288 MB)	160 GB (163840 MB)	1000 Mb/s

TABLE II. VM INSTANCE TYPES

VM Type [a]		VM Configurations				
		CPU	Cores	RAM	Strg	BW
1	High CPU	1700 MHz (1.7 GHz)	1	2048 MB (2 GB)	1024 MB (1 GB)	400 Mb/s
2	High Memory	1200 MHz (1.2 GHz)	1	3072 MB (3 GB)	2048 MB (2GB)	300 Mb/s
3	High BW	1300 MHz (1.3 GHz)	1	512 MB (0.5 GB)	2048 MB (2 GB)	500 Mb/s
4	High Strg	1400 MHz (1.4 GHz)	1	1024 MB (1 GB)	12288 MB (6 GB)	200 Mb/s
5	General	1500 MHz (1.5 GHZ)	1	1024 MB (1 GB)	3072 MB (3 GB)	200 Mb/s
6	General	1000 MHz (1.0 GHz)	1	512 MB (0.5 GB)	512 MB (0.5 GB)	250 Mb/s

a. *Inspired from https://aws.amazon.com/ec2/instance-types/*

TABLE III. POWER MODEL OF EACH PM

PM Workload (%)		Power Consumption of PMs (Watts)[b]		
		HP ProLiant ML110 G5	IBM System x3250 M3	IBM System x3550 M3
1	0%	93.7	42.3	66
2	10%	97	46.7	107
3	20%	101	49.7	120
4	30%	105	55.4	131
5	40%	110	61.8	143
6	50%	116	69.3	156
7	60%	121	76.1	173
8	70%	125	87	191
9	80%	129	96.1	211
10	90%	133	106	229
11	100%	135	113	247

b. Taken from *www.spec.org*

A. Performance Metrics

There are three performance metrics used to analyze the algorithms. These are described below:

1) Hosts Used: Hosts used is the number of PMs required to host (accommodate) all VMs in the workload. The goal is to minimize this number. The smaller the number the better is the performance.

2) Power Consumption: It is the total electrical power consumed by all PMs in a datacenter. The goal is to reduce the power consumption. Power consumption of a PM is calculated by using SPEC power model. Power consumption of each active PM at different load levels in a datacenter is calculated using the values provided in Table 3. At the end of the simulation, power consumed by all active PMs is then added together to get total power consumption of the datacenter.

3) Resource Utilization Efficiency: Resource utilization efficiency is how well the resources of a PM in each dimension are utilized. The goal is to increase utilization efficiency in all dimensions of a PM. For each PM, utilization percentage in each of its dimension i.e. CPU, RAM, BW, and Strg is calculated first. After that average utilization percentage of each PM in each dimensions is calculated.

VII. RESULTS

The experiments were conducted on a HP notebook PC running Windows 7 Home Premium with Core i5 CPU @ 1.60 GHz and 4 GB RAM. In each experiment all VMs were placed separately by FFDmean, FFDmedian, DP and L2. Average results of each algorithm in each performance metric are presented here. Fig. 1 shows a graphical representation of average hosts used by each algorithm in each experiment and Fig. 2 shows a graphical representation of average power consumption in kilo watts (KW) by each algorithm in each experiment. Fig. 3 shows a graphical representation of average resource utilization efficiency (%) by each algorithm in each experiment. To save space in figures FFDmean and FFDmedian are represented as Mean and Median. Table 4 shows a summary of results in each experiment.

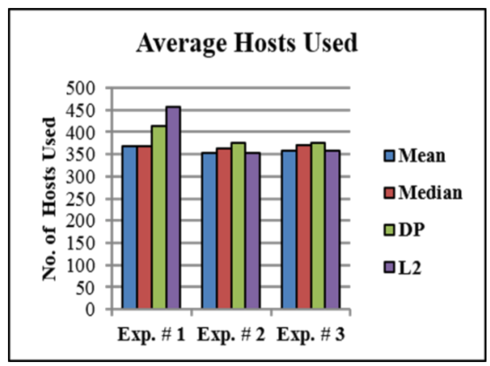

Fig. 1. Average hosts used in each experiment.

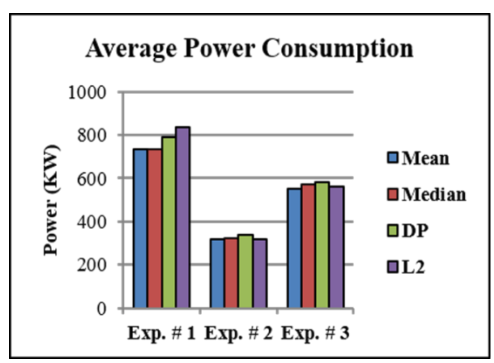

Fig. 2. Average power consumption in each experiment.

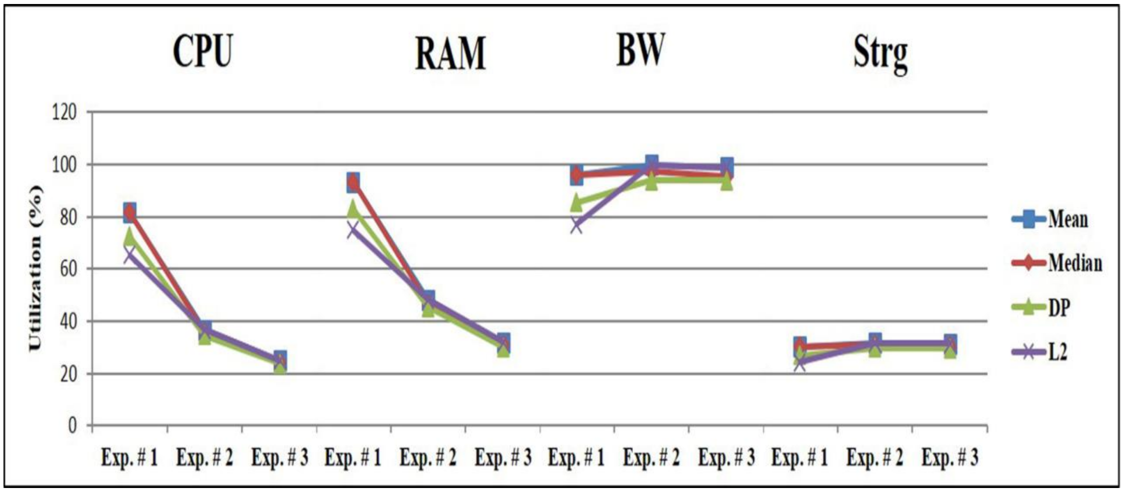

Fig. 3. Average resource utilizataion (%) in each experiment.

TABLE IV. SUMMARY OF AVERAGE RESULTS BY ALL ALGORITHMS IN ALL METRICS

Exp. #	Algorithms	Hosts Used	Power Consumption	Resource Utilization Efficiency (%)			
				CPU	RAM	BW	Strg
1	FFDmean FFDmedian DP L2	368 368 413 458	734.241 734.522 790.843 835.828	81.55 81.55 72.49 65.38	93.34 93.34 83 74.99	95.92 95.92 85.39 77.06	30.28 30.28 26.86 24.15
2	FFDmean FFDmedian DP L2	353 363 376 353	315.745 324.919 336.343 318.602	36.64 35.68 34.42 36.7	48.29 46.73 45.29 48.35	99.85 97.13 93.82 99.83	31.67 30.85 29.64 31.59
3	FFDmean FFDmedian DP L2	357 370 376 357	552.971 572.475 584 560.968	24.89 24.14 23.68 24.88	31.86 30.66 29.93 31.84	98.97 95.4 93.75 98.9	31.35 30.13 29.62 31.33

VIII. DISCUSSION

A. Hosts Used

In Exp. 1 FFDmean and FFDmedian saved 11% hosts compared to DP and saved 20% hosts compared to L2. In Exp. 2 FFDmean saved 6% hosts compared to DP and performed equally well as L2. FFDmedian saved 3% hosts compared to DP however it used 3% more hosts compared to L2. In Exp. 3 FFDmean saved 5% hosts compared to DP and performed equally well compared to L2. FFDmedian saved 2% hosts compared to DP however it used 4% more hosts compared to L2.

This shows that in Exp. 1 where PM resources were very limited compared to other experiments, FFDmean and FFDmedian remarkably saved hosts leaving behind DP and L2, however when resources were comparatively increased in Exp. 2 and Exp. 3 FFDmean outperformed DP and performed equally well as L2 however FFDmedian only performed better than DP.

B. Power Consumption

In Exp. 1 FFDmean saved 7.16% power compared to DP and 12.15% power compared to L2. FFDmedian saved 7.12% power compared to DP and saved 12.12% power compared to L2. In Exp. 2 FFDmean saved 6.12% power compared to DP and saved 0.9% compared to L2. FFDmedian saved 3.4% power compared to DP; however, it used 1.98% more power compared to L2. In Exp. 3 FFDmean saved 5.31% power compared to DP and saved 1.43% power compared to L2. FFDmedian saved 1.97% power compared to DP; however, it used 2.05% more power compared to L2.

This shows that like hosts used metric, in Exp. 1 where PM resources were limited compared to other experiments FFDmean and FFDmedian both outperformed DP and L2 in saving power. When PM resources were comparatively increased in Exp. 2 and Exp. 3 FFDmean outperformed both DP and L2 however FFDmedian only performed better than DP.

C. Resource Utilization Efficiency

Table 4 shows that in Exp. 1, FFDmean and FFDmedian performed equally in increasing utilization efficiency in all dimensions and outperformed both DP and L2. The effect of this utilization efficiency can be seen in other two metrics where FFDmean and FFDmedian outperformed very well than both DP and L2. In Exp. 2 FFDmean and L2 showed same utilization values and better than FFDmedian and DP, therefore their performance in other two metrics was almost same. FFDmedian increased up to 1% utilization in all dimensions compared to DP. Even with 1% increase in utilization

FFDmedian saved 3% hosts and 3.4% power compared to DP. This shows that even minor increase in utilization can bring a lot of effect. In Exp. 3 FFDmean and FFDmedian performed equally to L2. FFDmean and FFDmedian increased up to or more than 1% utilization compared to DP in all dimensions. With this minor change FFDmean saved 5% hosts and saved 5.31% power compared to DP, and FFDmedian saved 2% hosts and 1.97% power compared to DP.

This shows that with very limited resources in Exp. 1 FFDmean and FFDmedian remarkably outperformed DP and L2 in increasing resource utilization efficiency. By increasing PM resources in Exp. 2 and Exp. 3 utilization values of all algorithms became almost equal with minor difference. It is observed that even minor changes in utilization can bring a lot of effect in saving hosts and power.

From all experiment results, it is observed that our proposed algorithms FFDmean and FFDmedian remarkably outperformed DP and L2 when PM resources were extremely limited. Our algorithms also performed well when resources were increased, however the performance was not that remarkable compared to the prior situation. This shows that our algorithms can be useful in situations where resources are very limited.

IX. Conclusion

This research proposed two Vector Bin Packing algorithms for virtual machine placement called FFDmean and FFDmedian. These algorithms are essentially FFD variants which use mean and median respectively as heuristics to estimate size of a multi-dimensional VM. The performance of proposed algorithms was evaluated by comparing them to existing algorithms DP and L2 over three metrics i-e hosts used, power consumption and resource utilization efficiency. DP and L2 use dot product and L2-norm respectively to estimate the size of a VM.

Proposed algorithms were tested over three types of PMs (different in configuration) to evaluate their performance sustainability as the PM resources increase. It is observed that the proposed algorithms remarkably outperformed DP and L2 when PM resources were comparatively limited to other experiments. The algorithms also performed well when resources were increased, however the performance was not that remarkable compared to the prior situation. This shows that the algorithms can be useful in situations where resources are very limited.

X. Future Recommendations

Since this work was limited to only initial VMP, live VM migrations can be incorporated in this work. The algorithms were measured over only three metrics i.e. hosts used, power consumption and resource utilization efficiency this work can also be extended in future by using other metrics such as SLA performance degradation, etc. Moreover non-identical PMs can be used in the experiments.

Acknowledgement

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Implementation of a Hierarchical Hybrid Intrusion Detection Mechanism in Wireless Sensors Network

Lamyaa Moulad
Computer Science Dept.
ENSEM/EST Casablanca, Morocco

Hicham Belhadaoui
Computer Science Dept. EST
Casablanca, Morocco

Mounir Rifi
Computer Science Dept. EST
Casablanca, Morocco

***Abstract*—During the last years, Wireless Sensor Networks (WSNs) have attracted considerable attention within the scientific community. The applications based on Wireless Sensor Networks, whose areas include, agriculture, military, hospitality management, etc. are growing swiftly. Yet, they are vulnerable to various security threats, like Denial Of Service (DOS) attacks. Such issues can affect and absolutely degrade the performances and cause a dysfunction of the network and its components. However, key management, authentication and secure routing protocols aren't able to offer the required security for WSNs. In fact, all they can offer is a first line of defense especially against outside attacks. Therefore, the implementation of a second line of defense, which is the Intrusion Detection System (IDS), is deemed necessary as part of an integrated approach, to secure the network against malicious and abnormal behaviors of intruders, hence the goal of this paper. This allows improving security and protecting all resources related to a WSN. Recently, different detection methods have been proposed to develop an effective intrusion detection system for WSNs. In this regard, we proposed an integral mechanism which is an hybrid Intrusion Detection approach based on anomaly, detection using support vector machine (SVM), specifications based technique, signature and clustering algorithm to decrease the consumption of resources, by reducing the amount of information forwarded. So, our aim is to protect WSN, without disturbing networks performances through a good management of their resources, especially the energy.**

Keywords*—Wireless Sensor Networks (WSNs); Intrusion Detection System (IDS); anomalies; specification-based detection; Denial Of Service (DOS) attacks; hybrid intrusion detection system; support vector machine(SVM); false alarm; detection rate

I. Introduction

Sensors nodes are low power electronic devices that cooperate to form a network called wireless sensor network (WSN), often deployed in hostile areas, difficult to access, they are equipped with small batteries with limited energy, which makes very expensive and difficult to replace or charge these sensor's batteries [8].

Lately, the demand of wireless sensor networks (WSN) [1]-[3] have become a promising future to many new real applications, where data is communicated insecurely to critical destination, such as health monitoring, emergency, army, biometric application in airport, [8] etc. Thus, WSN are exposed to various malicious attacks which can generate an overconsumption of energy. Therefore, monitoring energy consumption is crucial topic to secure a WSN, which means that during the implementation, communication protocols dedicated to WSNs must consider the level of power consumption to provide optimal management [6] of this vital resource.

The goal of this work is to implement an integral security mechanism, a new hybrid intrusion detection system (HIDS) [28], [9] for WSN based on clustering algorithm, to reduce the volume of data forwarded through the network and decrease the exhaustion [7] of resources, especially energy. In general we have combined three main techniques: anomaly-based detection, to class data into normal and abnormal (binary classification), and detect abnormal behavior and anomalies. We have used, also, signature or misuse detection technique to detect known attack patterns, specifications based technique, and some other supporting techniques. Therefore, this combination, profit from the advantages of the cited detection techniques, and can absolutely offer a high detection rate and low false positive, to make a better decision in order to detect new kinds of intrusions.

The paper is organized as follows: In Section II, we provide background information about IDS [26] in WSNs and related works. Section III elaborates on the proposed scheme and architecture of our proposed Hybrid Intrusion Detection System. Section IV contains the simulation results with analysis of the proposed scheme are discussed. In Section V, we conclude our work with a further discussion of research directions.

A. Background of IDSs Security in WSNs

This paper examines one of the most important axes of Wireless Sensor Networks, which is security [21] and particularly Intrusion Detection Systems (IDS) [14]. As already stated, IDSs are defined as the second lines of defense; yet, key management and authentication represent just a first line of defense against just external attacks. Therefore, IDSs, allows detection and prevention from both internal and external [29] intrusions. Fig. 1 describes the process of IDSs.

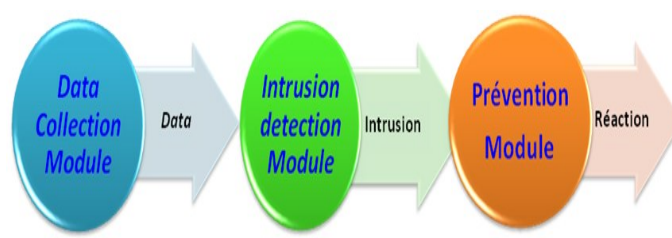

Fig. 1. Intrusion detection architecture.

Each IDS contains three modules:

1) Data Collection modules: Collect the information sent, received and forwarded by the sensors.

2) Intrusion detection module: It depends on the intrusion detection technique used (Signature, Anomaly or Specification-based detection), IDS agent sends an alarm message mentioning the suspect node, to all network.

3) Intrusion detection module: In case of abnormal behavior the IDs send an alarm to the rest of components, and remove the intruder.

IDSs [26], [20] are classified into three main techniques: signature based, anomaly based, and specification-based detection (Fig. 2).

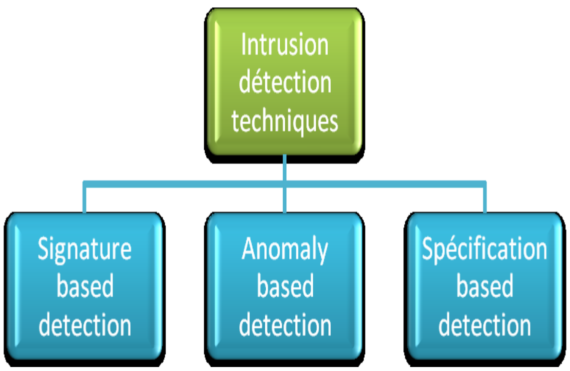

Fig. 2. Intrusion detection techniques [31].

Misuse detection (Signature): Misuse detection based IDS have a predefined collection of main rules that is formed of previously known security attacks, so the behavior of nodes is compared with well-known attack patterns already existing in database. Although, that this technique needs knowledge of attacks' patterns and can't detect new attacks [30], so we always have to update attack signatures database.

Anomaly detection: This technique works on the basis of threshold; it compares the behavior of observed nodes with normal behavior. This model first describes normal behaviors which are established by automated training (as SVM) and then flags as intrusions any activities varying from these behaviors. It is able to detect new intrusions, but, it has a major disadvantage of missing out on well-known attacks. The anomaly based model has a high detection rate, but it has also a high false positive rate.

Specification-based detection: This technique is based on deviations from normal behaviors defined by neither machine learning techniques and nor by training data. Yet, specifications are defined manually and monitor any action by applying the predefined specifications.

However, to improve the level of detection, we can use another solution called the hybrid Intrusion Detection model, which is a combination of detection techniques already mentioned. Therefore, this combination allows the system to benefit from theirs advantages. This mechanism can make a better decision, which might detect new kinds of intrusions with higher detection rate and lower false alarm.

II. Related Works

In previous works, and as we consider proposing hybrid HIDS system, there are some proposed hybrid schemes integrated for clustered sensor networks using the interesting study done by [4].

In [16], [4] a detection system is proposed for WSN and to get an hybrid model (HIDS), the version combine Cluster-based and Rule-based intrusion detection is used and evaluated the intrusion detection using hybrid technique and detection, the results performs better in terms of energy, but the model is still weak because it cannot detect new intrusions.

In [15], Su et al. [4] proposed energy efficient HIDS for CWSNs. They use intrusion detection and intrusion prevention techniques to form a hybrid security system. Their system combines collaboration-based intrusion detection and member node monitoring. The scheme fails because of using just the shared key between cluster head (CH) and member node (MN).

Abduvaliyev et al. [14], [25], [4] proposed a hybrid IDS (HIDS) based on two techniques, anomaly and misuse detection in a cluster WSN (CWSN) environment. The results showed that the model proposed give a high detection rate and low level of energy consumption. However, this model does not detect most known network attacks.

Yan et al. [4] proposed hierarchical IDS (CHIDS) based on clusters. The authors took advantage of this approach and install on each cluster-head an IDS agent that contains three modules: a supervised learning, an anomaly detection based on the rules and decision-making module. The simulation results showed a high detection rate and lower false positive rate. But, the implementation of this detection mechanism requires many calculations in cluster-heads, and that can decrease the network lifetime.

Hai et al. [23], [4] proposed a hybrid, lightweight intrusion detection system for sensor networks (SN), using the scheme of Roman et al. [5]. Intrusion detection scheme profit from advantage of cluster-based protocol to form a hierarchical network (HN) to give an intrusion framework based on anomaly and misuse techniques. In their proposition, IDS agent consists of two detection modules, local agent and global agent. The authors apply their model in a process of cooperation between the two agents to detect attacks with greater accuracy. But, the disadvantage of this scheme is the sharp increase in signatures, which can lead to an overload of the node memory.

In recent work, Coppolino et al. [6], [4] presented a hybrid, lightweight, distributed IDS (HDIDS) for WSN This IDS uses both misuse-based and anomaly-based detection techniques. It is composed of a Central Agent (CA), which performs highly accurate intrusion detection by using data mining techniques, and a number of Local Agents (LA) running lighter anomaly-based detection techniques on the motes.

Sedjelmaci et al. [4] implemented a new Framework for securing WSN that combines cryptography and IDS technology to detect the most dangerous network attacks, and provide a trust environment using clusters. The results show that the model performs well in terms of detection rate, although it generates high overhead and energy consumption.

Y. Maleh et al. [24] implemented a hybrid, lightweight IDS model for sensor networks, the ids using cluster-based architecture. This model uses anomaly detection based (SVM) algorithm and signature. The proposed hybrid model give efficiency in terms of detecting attacks and false positives rates compared to previous schemes, however the charge of CH can cause an early dysfunction of this element.

III. Proposed Hybrid IDs

The proposed model contains specification based technique, signatures based technique using some fixed rules representing most dangerous attacks in WSN, and anomaly detection based on SVM [5], to confirm the malicious behavior of a target identified by behavior detection technique, and analyze data for classification.

Fig. 3 below provides our proposed hybrid model.

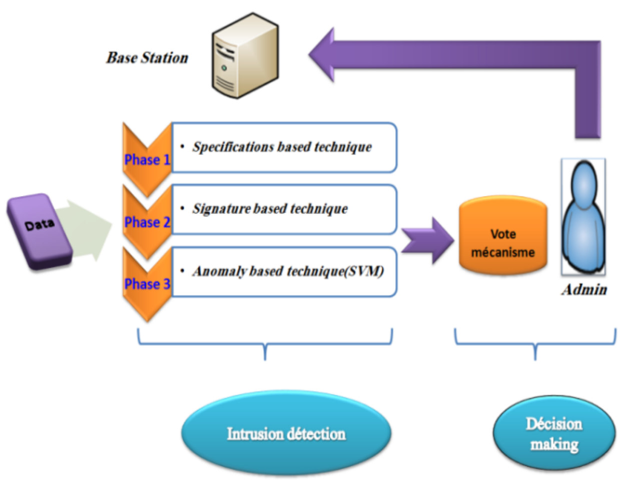

Fig. 3. Architecture of proposed hybrid IDS.

A. Intrusion Detection Used Techniques

1) Behavior based detection (specification-based)

This technique adopts the same principle as the detection based anomalies that, any deviation of normal behavior is considered as intrusion. This technique fit a statistical model (usually normal behavior) to the data provided. Then, It applies a statistical inference model to determine if an instance belongs to this model or not. When a low probability is being generated from the learned model, concerned bodies are reported as anomalies.

However, the definition of the behavior model is performed in a manual way and not automatically using a learning algorithm, because it uses thresholds defined by the user to identify areas of abnormal data. It is similar to a No parametric learning (statistical) the techniques that offer greater flexibility with respect to parametric learning techniques because they require no prior knowledge of the data distribution. This simplifies the detection system, and significantly reduces the rate of false negative detections. Compared to the detection based on anomalies, this technique seems to be best suited to the limitations of sensor networks.

2) Anomaly detection using SVM

In this section a detailed description of SVM and feature selection are presented:

a) Support vector machines

Support vector machines (SVM) [19] are defined as a set of supervised learning techniques used for classification of network behavior. The main goal of SVM classifier is to determine a set of vectors called support vectors to construct a hyperplane (see Fig. 4) in the feature spaces. Here, a distributed binary classifier to normal and abnormal, which permits detection of every malicious act.

$$w = \sum_{i=1}^{n} \alpha_i y_i x_i \quad \min\left\{\frac{\|w\|^2}{2} + C\sum_{i=1}^{n}\varepsilon_i\right\} \tag{1}$$

$\sum_{i=1}^{n}\varepsilon_i$ is the constraints on the learning vectors, and C is a constant that controls the tradeoff between number of misclassifications and the margin maximization.

Equation (1) can be dealt by using the Lagrange multiplier [17]:

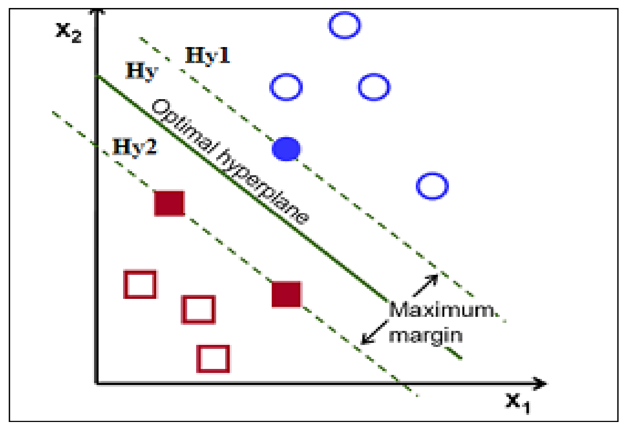

Fig. 4. Hyperplane.

Classification hyperplane given the training datasets,

$(x_i, y_i)\ i=1,\dots n\ y_i \in \{-1,+1\},\ x_i \in R^d$

The hyperplane that have a maximum margin:

$W.x = b$

Where, w is a normal vector and b is offset. In order to find the optimal hyperplane, we must solve the following convex optimization problem:

$$maximise\ l(\alpha) = \sum_{i=1}^{n}\alpha_i - \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}\alpha_i\alpha_j y_i y_j k(x_j, x_i) \tag{2}$$

$$subject\ to \sum_{i=1}^{n} y_i\alpha_i = 0, and\ 0 \le \alpha_i \le C\ for\ all\ 1 \le i \le n$$

K(x_j, x_i) is the kernel function and α_i are the Lagrange multipliers. Referring to the condition of Kuhn-Tucker (KKT), the x_is that corresponding to $\alpha_i > 0$ are called support vectors (SVs).

Once the solution to (2) is found, we get [17]:

$$y_i(w.x_i + b) \ge 1 - \varepsilon_i, \varepsilon_i \ge 0, 1 \le i \le n \tag{3}$$

Thus the decision function is written as:

$$f(x,a,b) = \{\pm 1\} = sgn\left(\sum_{i=1}^{n} y_i \alpha_i k\left(X_j X_i\right) + b\right) \quad (4)$$

SVM is more suitable for intrusion detection in case where new signature is detected. Also, SVM provide low false positive and satisfied results with low training time compared to neural networks. [18].

3) Misuse based detection (Signature)

Misuse or signature based detection is used to prevent network against malicious behavior using a set of rules. There is five main rules for each attack, rule to detect an excessive demand of energy (E(d)>E. The rule to detect the Selective forwarding attack, represented by the number of packets dropped (PDR). The rule to detect the Hello flood attack is the received signal strength (ISSR) at the IDS agent, The rule to detect the Black hole attack is defined by the number of RDP. Finally, the rule to detect the wormholes attack which is the power of signal.

4) Cooperative decision making Approach (voting mechanism)

In this approach, each node participates in the detection and management of intrusion decision.

The goal of the decision making model is to analyze the results of all detection techniques used which are the behavior's specification, anomaly and misuse detection models_and validate when an intrusion occurs or not. Then, it sends the results to the administrator of network, to help them handle the state of the system, update the database of signatures, make further countermeasures, and prevent the system by sending an alarm if an intrusion occurs.

B. Network Structure and IDS Agents Location Process

1) Structure of the network: As mentioned before, the detection approach uses cluster-based topology (see Fig. 5) [22] to decrease the quantity of packets forwarded through the network and increasing the network lifetime. by designating a leader of the group called cluster-head (CH) - via a cluster election - that collect data received from member nodes to prepare it for the mobile sink (MS) use, then and while moving through CHs, the MS aggregate data (collected by CHs), instead of sending it to the base station (BS), in order to reduce the charge and also support the CH.

The base station starts the process of CH election, CHs calculate residual energy using the equation Vi(t) = [Initial – Ei(t)] / r, where Initial is the initial energy, r is the current round of CH selection and Ei(t) is the residual energy. According to collected values, the Base station (BS) calculates the average value and average deviation .then a CH is elected dynamically according to his residual energy.

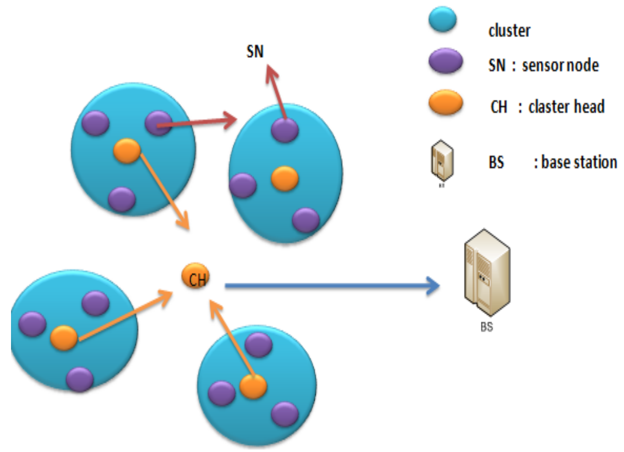

Fig. 5. Network structure.

2) IDS location process: In this proposed scheme, an IDS agent is located in each sensor node. Each cluster contains two kinds of agents: local and global IDS agents. Because of the limited energy resources, each agent is only active when needed, to avoid the above issues, we place a sensor node called mobile sink which act as an intermediate between the CH and the BS. The mobile sink (MS) is kept in moving state so that the intruder may not find the location of the node easily. The proposed cluster-based wireless sensor networks topology is shown in the (Fig. 6). The MS gathers the data from each of the cluster-head when it moves near to the corresponding clusters. The mobile sink reduces the work load of the cluster-head. While the cluster-head sending the data to the mobile sink, the energy of the cluster-head is automatically reduced [12], [11].

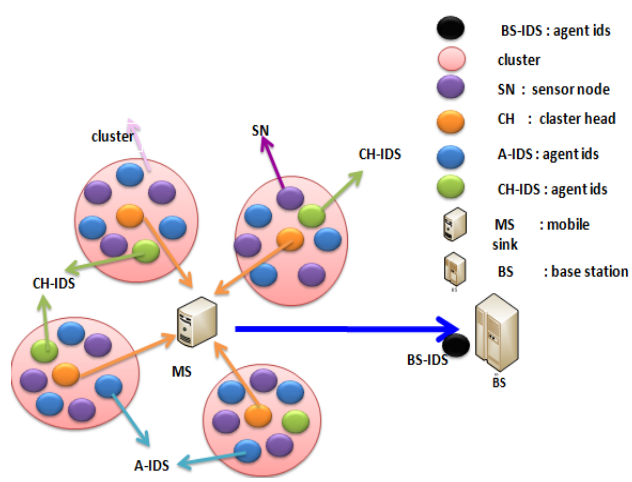

Fig. 6. Location of IDS in wireless sensor network.

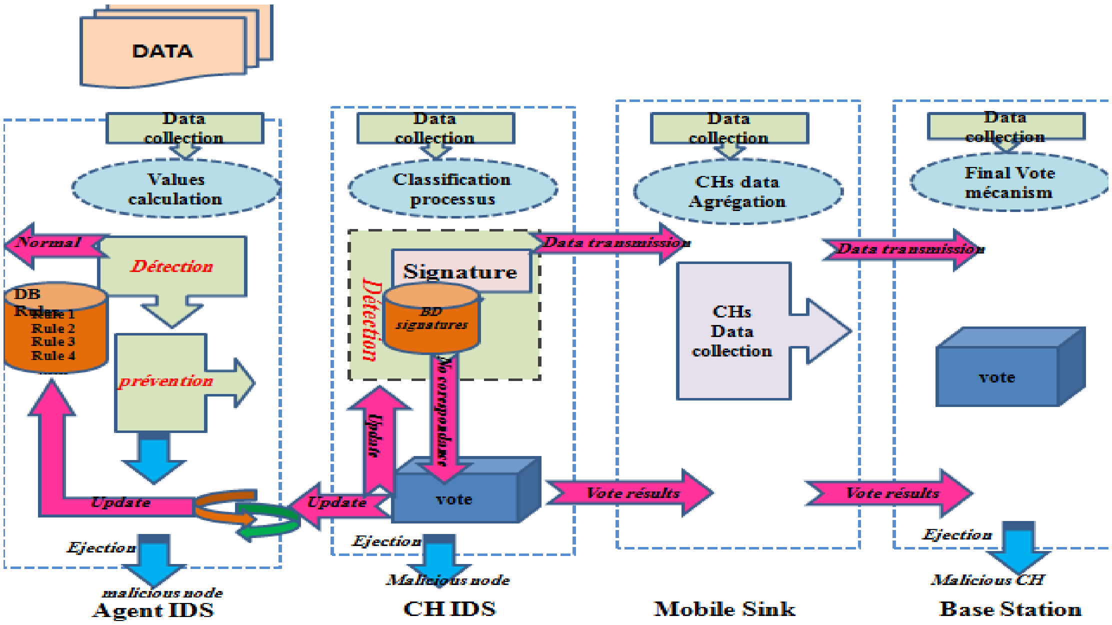

Fig. 7. Process of detection between WSN IDS agents components.

Fig. 7 explains well the process of IDS agents' location in network.

In this hybrid IDS architecture, and by using hierarchical architecture, our aim is to utilize cluster-based protocols to save energy, and reduce computational resources and data transmission redundancy. In this context, we proposed this enhanced intrusion framework based information sharing.

a) Intrusion detection at Member nodes: Data Collection modules and intrusion detection are in general, the principal components in this type of agent.

- Data Collection Module: Is responsible to collect the data sent, received and forwarded by sensor. This node saves in his database, the id of the node analyzed and compute values of some parameters, such as Energy, NPD, NPS, RSSI, NRM, JITTER … in every node.
- Intrusion Detection Module: This module apply a mechanism that the cluster have a special behavior, so any deviation of the normal values fixed for parameters mentioned, represent an abnormally that need to be fixed immediately, by alarming CH of the cluster. This IDS can supervise even the CH when needed.

b) Intrusion detection at CHs: Proposed clustering algorithm chose for every cluster, the CH that has more power resources to aggregate data from cluster members. This powerful node is composed of three modules.

- Data Collection Module: Is responsible of collecting packets sent by the IDS agent. This message contains the address of the node analyzed by the IDS agent then, transmitted to the abnormality detection module for intrusion detection process.

Behavior classifier:

Then the Behavior classifier classifies the node behavior of collected data already transmitted by the ids agent, as trustworthy if no match with database signature, attacker if rule signature is confirmed, and suspect if not an attack but the behavior still shows an abnormality in this case we need to apply detection module for learning based on SVM.

After computation and analysis of the values collected and the fixed rules, the behavior is classified into:

```
Classification {

If (packet is Normal)
  { Launch of voting process }

Elseif (packet matches a signature)
  {Declare the intruder node with exclusion and
classification of the attack)
 }

Else { (calculate SVM)
 Launching voting processes}
}
```

- Intrusion Detection Module: (Signature + SVM) This kind of IDS uses discovery protocol based on the fixed rules signatures representing most dangerous attacks in Wireless Sensor Network (Section III, Phase 3), then transmitted to the abnormality detection module for learning and classification process.
- Voting Mechanism: Regarding collaborative process, the cluster-head uses the voting mechanism. If there is no match between the intrusion detected by predefined signatures attackers and the anomaly detection, IDS agent sends a message to the CH, this one use voting to make a final sure decision on the suspect node. If more than ½ of IDS nodes located in the same cluster voted

for malicious suspected target, the CH rejects that node and calculates the rule of this new intrusion detected. The CH sends an update message to all IDSs that are in the same cluster and CHs neighbors. This message contains the ID of the malicious node and this new rule (and signatures).When IDS agent receives this message it is an update of its signature table.

Mobile sink:

Each mobile sink (MS) gathers the data from each of the cluster-head in the same radio coverage area when it moves near to the corresponding clusters to reduce the work load of the cluster-head. When the cluster-head transmits the data to the mobile sink [32], the energy of the cluster-head is reduced ,this information will be transmitted to the base station for a monitoring process.

c) Intrusion detection at Base station (BS): Each mobile sink gathers the data from each of the cluster-head in the same radio coverage area when it moves near to the corresponding clusters to reduce the work load of the cluster-head. When the cluster-head transmits the data to the mobile sink, the energy of the cluster-head is reduced; this information will be transmitted to the BS for monitoring process.

Fig. 8 below explains the global Structure of our effective hybrid proposed intrusion detection model.

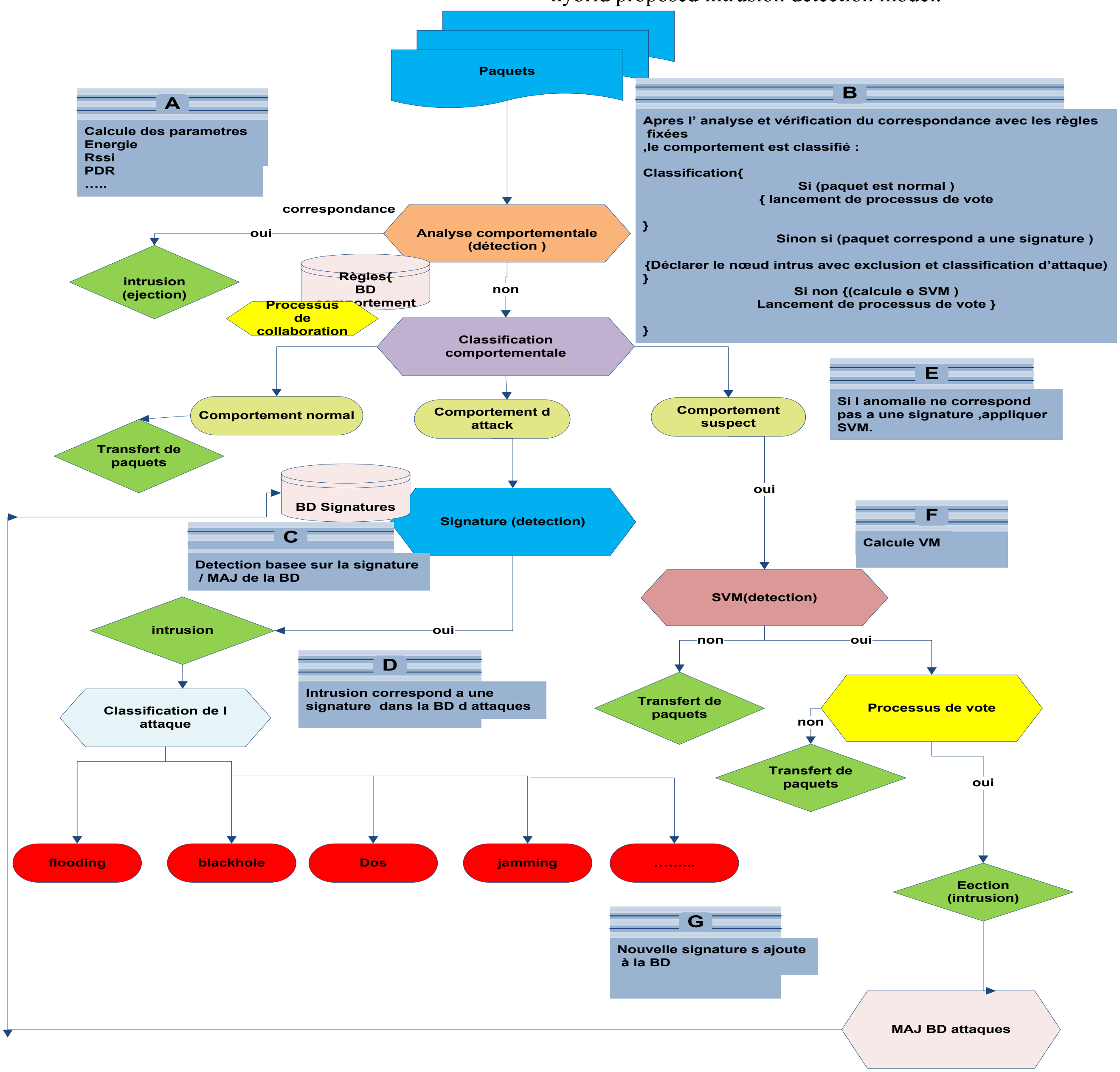

Fig. 8. Structure of the proposed intrusion detection model.

C. Dynamic Process for Intrusion Detection System

In the suggested approach, if (1/2) of IDS nodes within the cluster have consumed more than 25%, 50% and 75% (in tree level) of their energy; new IDSs are elected and receive the actual set of intrusion signature from the CH. New IDSs election depends on the residual energy and the placement process proposed by Khalil et al. new IDS nodes are elected, they compute locally the SV and the distributed algorithm for training SVMs is performed. This model helps to save energy of network components.

IV. Experimental Evaluation

To evaluate the proposed hybrid IDSs, we used the KDDcup'99 dataset [10] as the sample to verify the efficient of the hybrid detection mechanism and valid it by comparing the results with scheme proposed by Abduvaliyev et al. [14] and W. T. Su, K.M. Chang [15]. According to [13], the false positive rate (false alarm), detection rate and energy generated by IDS agents were to determine the effectiveness of our proposed scheme.

A. Dataset

The KDD 99 intrusion detection dataset is developed by MIT Lincoln Lab in1998, each connection in the dataset has 41 features and it's categorized into five classes: normal and four attack behaviors (Dos, Probe, U2r, R2l) [12].

Our analysis is performed on the "KDD" intrusion detection benchmark by using its samples as training and testing dataset. We focus on all categories of attacks and specially Dos attacks, which are defined as anomalies behavior.

The training data used at each IDS comprises of 50 normal and 50 anomalous samples include Dos attacks [17].

To determine the effectiveness of our proposed hybrid intrusion detection system we tried to analyze some important metrics, which are: detection rate (DR), the false positive rate (FP) and energy, according to the formulas:

$$Detection\ Rate = \frac{\text{Number of detected attacks}}{\text{Number of attacks}} * 100\%$$

$$False\ Positive\ Rate = \frac{\text{Number of misclassified connections}}{\text{Number of Normal connections}} * 100\%$$

$$Total\ Energy\ consumption\ Et = \text{EA} + \text{EM}$$

1) Detection Rate (DR): is the ratio of attacks detected on the total number of attacks;

2) False positive rate or false alarms (FR): is the ratio between the number classified as an anomaly on the total number of normal connections;

3) Total energy consumption (EC): it calculate the total amount of energy consumed in all nodes in the network.

B. Simulation Results

The network is composed of 10 clusters that contain 1-7 nodes over all the nodes that are static, distributed in a field of 100×100, an interference model for radio simulations. The rest of the specifications of a sensor node for detection module are defined in the table below (see Table 1, Fig. 9).

TABLE I. Simulation Parameters

Parameter	**Value**
simulation time	900 sec
simulation area	100 *100m
Number of nodes	100
radio Model	Lossy
Number of cluster	10
IDS agents / cluster	1-7
routing Protocol (Rp)	HEED modifier
MAC	TDMA
radio range	20m
Initial energy	5 Joules
Power consumption for transmission	1.6W
Power consumption for reception	1.2W
Power consumption in idle state	1.15W

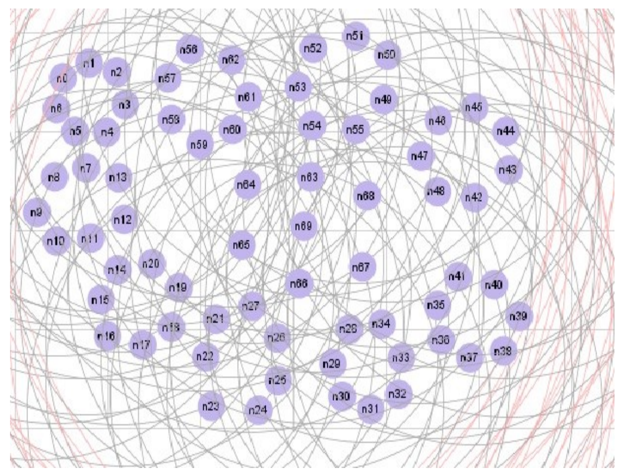

Fig. 9. Scenario of 10 clusters.

1) Detection rate: Fig. 10 shows that if we increase the number of nodes, the scheme become very effective. So, our proposed model performs better in term of detection rate, exceeding over 98.5% comparing to schemes proposed by Abduvaliyev et al. and W. T. Su, K.M. Chang.

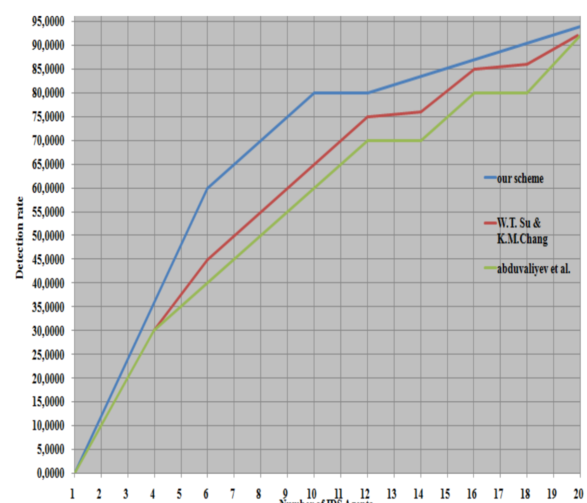

Fig. 10. Detection rate.

2) False positive rate: The probability of false alarms is given in Fig. 11. It indicates that the increasing number of nodes provide an increasing in the probability of a collision. Fig. 11 shows a low false alarm (1.8%) and a short detection time, compared to the scheme proposed by Abduvaliyev et al. and W. T. Su, K.M. Chang.

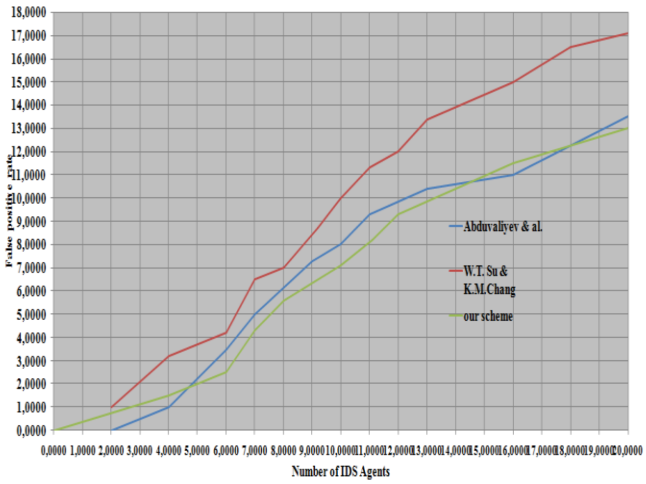

Fig. 11. False positive rate.

3) Energy Consumption: Fig. 12 illustrates the total of energy consumed in the sensors network deployed. It is clear that our model is the less energy consuming scheme comparing to the other schemes proposed by Abduvaliyev et al. and W.T. Su, K.M. Chang.

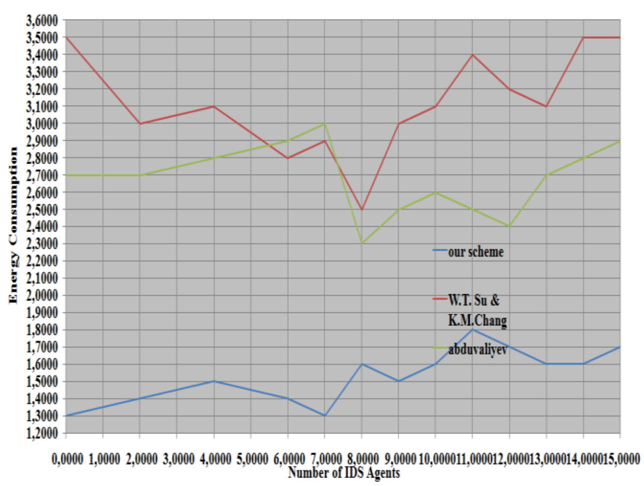

Fig. 12. Energy consumption.

Detection and false positive rates were respectively of the order of 98.5% and 1.8%. As shown in Fig. 10 and 11, the two diagrams show a high detection rate and low false alarms and a short detection time, compared to the scheme proposed in the reference.

Furthermore, our detection model requires less energy to detect these attacks, compared to the approach used by the authors mentioned. This improvement was achieved through our use of a cluster-based topology that aims to select a single node in a cluster (cluster-head) to transmit data aggregated at Mobile sink, which allows grouping packets from cluster-heads, then send it to the base station, especially that each IDS agent is based on a policy that minimizes packet transmission, which, in turn, will save energy. In conclusion, we can say that our approach improves network lifetime.

V. Conclusion

In this paper, we have implemented a security mechanism which is a hybrid Intrusion Detection approach based Anomaly Detection, based on support vector machine (SVM), specifications, and the Misuse Detection WSN, using the clustering algorithm to decrease the consumption of resources specially the energy by reducing the amount of information forwarded, so, our aim was to a safe WSN without damaging the network, by the good management of resources specially the energy. All results show that all attacks are detected with low false alarm and high detection rate.

As the future research directions, we will analyze, evaluate and implement our model with various attacks in a real environment; also a soft hybrid model will be proposed and compared to this present model and implemented in a large-scale sensors network.

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A Novel Design for XOR Gate used for Quantum-Dot Cellular Automata (QCA) to Create a Revolution in Nanotechnology Structure

Radhouane Laajimi
High Institute of Technological Studies of Sousse (ISET), 4023 Sousse Erriadh, Tunisia
Higher Institute of Applied Sciences and Technology of Sousse (ISSAT), University of Sousse, Tunisia

Lamjed Touil
High Institute of Technological Studies of Sousse (ISET), 4023 Sousse Erriadh, Tunisia
Networked Objects Control Communications Systems Laboratory, University of Sousse, Tunisia

Ali Ajimi
High Institute of Technological Studies of Sousse (ISET), 4023 Sousse Erriadh, Tunisia

Ali Newaz Bahar
Department of Information and Communication Technology, Mawlana Bhashani Science and Technology University, Tangail, Bangladesh

***Abstract*—Novel digital technologies always lead to high density and very low power consumption. One of these concepts is Quantum-dot Cellular Automata (QCA), which is one of the new emerging nanotechnology-based on Coulomb repulsion. This article presents three architectures of logical "XOR" gate, a novel structure of two inputs "XOR" gate, which is used as a module to implement four inputs "XOR" gate and eight inputs "XOR" gate using QCA technique. The two inputs, four inputs, and eight inputs QCA "XOR" gate architectures are built using 10, 35, and 90 Cells on 0.008 μm^2, 0.036 μm^2 and 0.114 μm^2 of areas, respectively. The proposed "XOR" gate structure provides an improvement in terms of circuit complexity, area, latency and type of cross wiring compared to other previous architectures. These proposed architectures of "XOR" gate are evaluated and simulated using the QCADesigner tool version 2.0.3.**

Keywords—QCA exclusive-OR; XOR gate; quantum-dot cellular automata (QCA); nanotechnology; majority gate; unique structure; QCA designer

I. Introduction

Nowadays, the enormous increase in the number of transistors in a single chip, furthermore the reduction of the size of the transistors is an essential challenge for the design of the integrated circuits and in the VLSI technology. The problem is that in this CMOS technology, the size reduction of the transistors is limited and almost impossible beyond 10 nm since it can introduce the abnormal quantum behaviour at the nanometric scale [1]-[3].

In order to overcome this problem, and to obtain high density, the speed with low power consumption Craig Lent and al introduced a new paradigm of the architecture of calculation. This paradigm rises from a series of developments carried out in the years 1980, on the study of systems to a low emerging number of electrons of new capacities in epitaxy allowing the manufacture of gas 2D of electrons by GaAs/AlGaAs. This paradigm is quantum-dot cellular automata (QCA) technology [2], [4].

A number of advantages stem from this new technology. The first is the use of the fundamental states of elementary cells to encode information (Computing with the ground state). As in CMOS technology, maintaining the ground state requires no external energy input, and is relatively stable. This stability of the ground state can, therefore, be used as memory since once prepared, the cell remains in principle in the ground state indefinitely.

A second advantage is that the communication between adjacent cells made by Coulomb repulsion. Inside the automaton, it is not the loads, but the information itself that moves. This eliminates the need to individually control each of the internal elementary cells. This also implies that the energy is supplied to the elementary input cells only and the system, being no longer in its fundamental state, relaxes to the latter. Then the result can be read out. This operation allows a minimum of energy to perform the calculations and minimizes the connections to the cells inside the QCA. Considering that a QCA is composed of only a few input bits for several tens of internal cells, the energy efficiency of a device of this type becomes substantial. QCA technology also has the most advantages in terms of density (10^{12} devices/cm^2), frequency or speed (Range of Terahertz) and especially in terms of energy dissipation (100 W/cm^2). At this last term, several works have been carried out on the calculation of the dissipation in various operating regimes.

This QCA technology composed of an array of cells, in each one there are four several quantum dots at the corner of a square. Because of the Coulomb interaction, electrons can only occupy two "diametrically" opposed quantum dots. These two states or polarizations correspond to the electrons positioned on the diagonals square. When the electrons are in the lower corners left and higher right, polarization is defined as P= +1 and in the diagonal opposed, it is P= -1. It is also possible to carry out planar crossings in using a turned version of 45° of a cell as shown in Fig. 1.

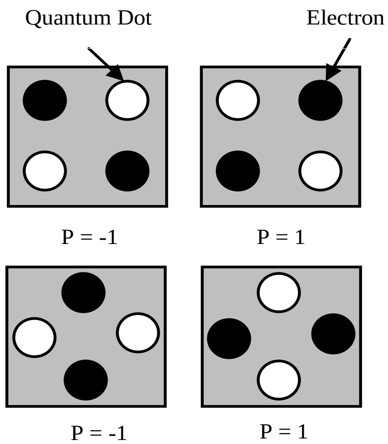


Fig. 1. Different polarizations of the quantum.

Assuming that the quantum dots at the corners of 1 to 4 (in order), we deduce that the electrons can only occupy points 1 and 3 (or 2 and 4). This is why each cell has a bistable behaviour which can facilitate its use in cellular networks on a very large scale. By taking advantage of the physical interaction between the neighbouring cells, it is then possible to implement various logical functions. The two great advantages of QCA technology is characterized by an interaction between purely Coulombic cells, and between these cells, there is no charge transport [5].

The information (logic 0 or logic 1) can propagate from input to the output of the QCA cell only by taking advantage of the force of repulsion as shown in Fig. 2.

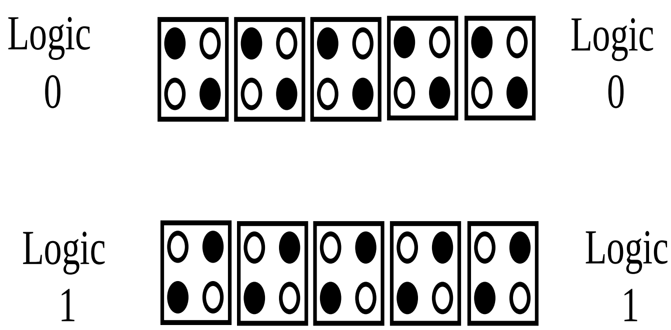


Fig. 2. Different operations of a QCA wire propagation with logic 0 and logic 1.

Thanks to these arrays of QCA technology which can be regular or irregular, the realization of various logical functions is possible. Several efforts have been devoted on a single QCA device using different approaches. Magnetic, semiconductor and molecular implants were continued, until the obtaining of the first logic functions, such as the inverter, gate shown in Fig. 3 and three-input majority voter (MV) shown in Fig. 4, which are the most important logic gate in QCA circuits.

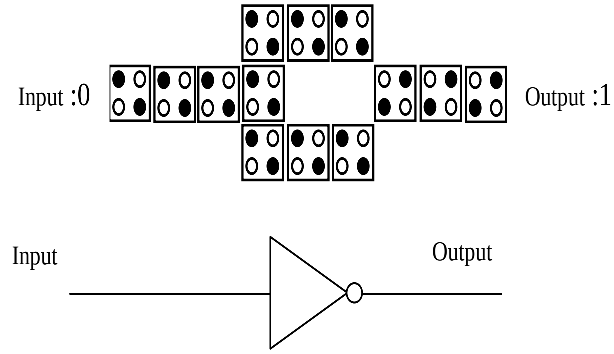


Fig. 3. QCA representation of inverter gate.

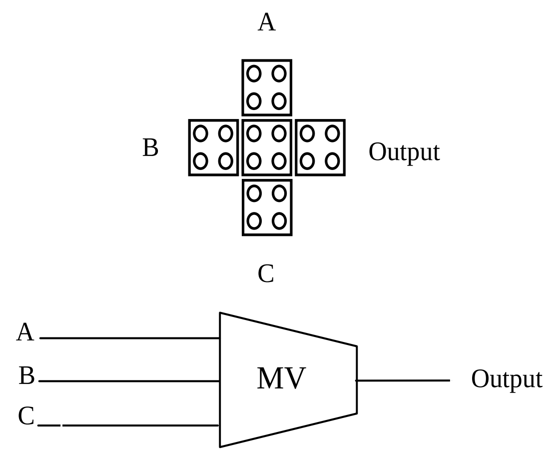


Fig. 4. QCA representation of majority voter (MV) gate.

The MV gate can behave as gate AND or gate OR logic depending on the majority logic value of its inputs. The logic function of the MV is given by this equation:

$$Output = A.B + B.C + C.A \quad (1)$$

Where, A, B, and C are the inputs of the majority voter (MV).

If one of the inputs of MV is fixed to 1 OR gate will be formed and the output will be expressed as:

$$Output = A+B \text{ when } C=1 \quad (2)$$

If one of the inputs of MV is fixed to 0 AND gate will be formed and the output will be expressed as:

$$Output = A.B \text{ when } C=0 \quad (3)$$

One of the approaches that have been proposed to make a calculation with a set of QCA cells is to apply a suitable voltage to a cell or clock [6], [7]. This involves adjusting the tunnel barriers between quantum dots in order to make the transfer of electrons from one point to another.

According to Fig. 5, each QCA cell is clocked by a clock system composed in general of four phases which are:

Switch phase: In this phase, the cells start without polarization and with low potential obstacles, while its obstacles have been raised during this phase.

1) Holding phase: In this phase the barriers are high.

2) Release phase: In this phase, the barriers are lowered.

3) Relaxation phase: In this phase, the barriers remain lowered as the previous phase. But they keep the cells in a non-polarized state.

In a clocking zone, the schema of the interdot barriers is presented in Fig. 6.

Based on the position of the potential barrier, the arrays of QCA cells in each phase have different polarizations. There are four phases; every phase has its own polarizations as shown in Table 1.

The rest of this paper is organized as follows: first, we describe the background of logical “XOR” gate or Exclusive OR gate with QCA technology. In the next, we describe different proposed 2-input, 4-input and 8-input of QCA “XOR” gate architectures with simulations results. In section IV the proposed QCA “XOR” gate architectures are evaluated and analysed. Finally, the conclusion appears in Section V.

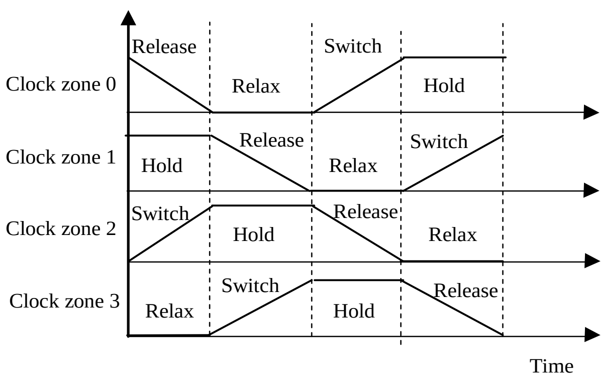


Fig. 5. Four phases of QCA clock zones.

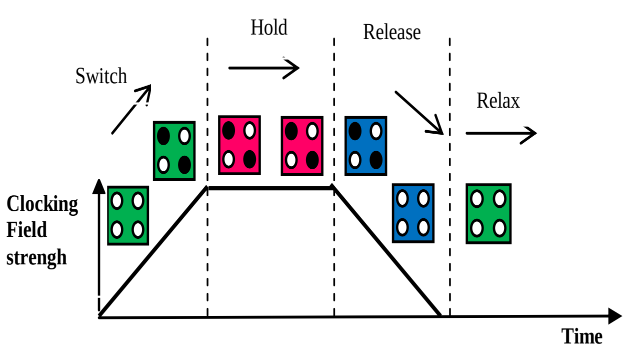


Fig. 6. Schematic of Interdot barriers in a clocking zone.

TABLE I. OPERATION OF QCA CLOCK PHASES

Clock Phase	**Potential Barrier**	**Polarization state of the Cells**
Hold	Held High	Polarized
Switch	Low to High	Polarized
Relax	Low	Unpolarized
Release	Lowered	Unpolarized

II. BACKGROUND OF LOGICAL “XOR” GATE OR EXCLUSIVE OR GATE

In this section, a description of a digital circuit called “XOR” gate is presented. It is an important digital circuit which is used in many different types of computational circuits such as Arithmetic logic circuits, Multiplexer, Full adder, Comparators and Error detection circuits.

An Exclusive “OR” gate or “XOR” gate is a digital logic gate composed of more inputs and only one output as shown in Fig. 7.

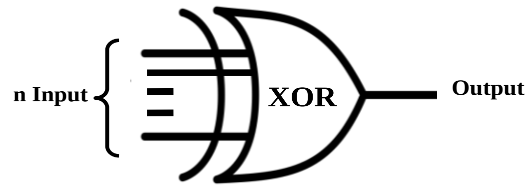


Fig. 7. General block diagram of “XOR” gate.

The output of a “XOR” gate is obtained true only if one of its inputs is true. When both of a “XOR” gate’s inputs are false, or if both of its inputs are true, the output of a “XOR” gate is obtained false.

In order to design two inputs XOR gate, different architectures are proposed, but most of the researcher’s designers are based on three stages: “AND” stage, “NAND” stage and “OR” stage. Where, “a” and “b” are the inputs, “Out” is the output signal as shown in Fig. 8.

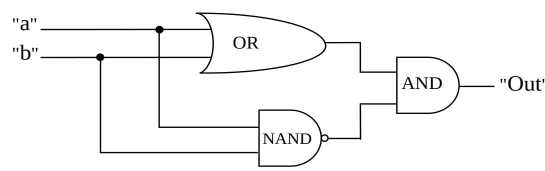
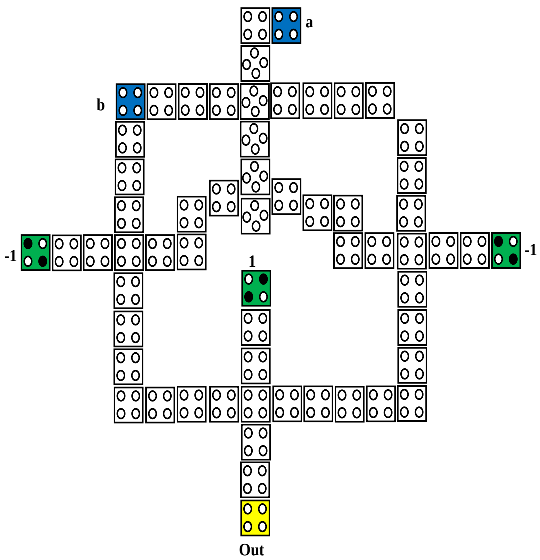


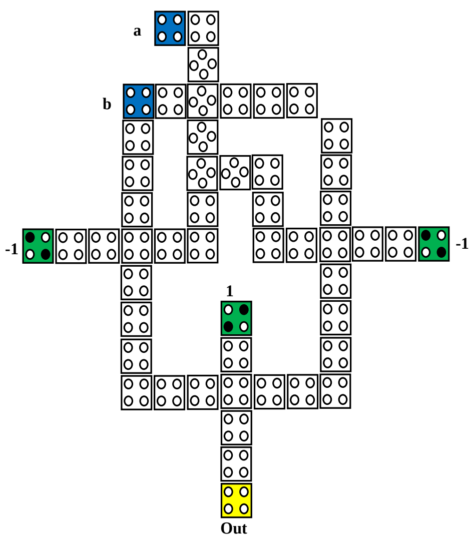
Fig. 8. Schematics of the basic architecture of “XOR” gate.

The recent previous structures of two inputs QCA “XOR” gate design are shown in Fig. 9. In [8] M.T. Niemier has designed a QCA “XOR” gate consists of 60 cells, 0.09 μm^2 area, 5 gate count and 1.5 clock zone latency as shown in Fig. 9(a). This architecture has an important number of cells and provides a large area. In order to overcome these problems, S. Hashemi et al. [9] proposed a new 2-input QCA “XOR” gate shown in with Fig. 9(b), with only 54 cells, 5 gate count, 0.08 μm^2 area and 2 clock zone latency. In order to decrease the number of cells, another structure is proposed by Chabi and al [10] which consists of 29 cells, 4 gate count, 0.03 μm^2 area and 0.75 clock zone latency as shown in Fig. 9(c). Fig. 9(d) shows another design proposed to reduce the area of the QCA “XOR” gate by G. Singh et al. [11], using two inverters, three inputs, and five inputs majority gate, with 28 cells, an area of 0.02 μm^2, 28 gate count and 0.75 clock zone latency.

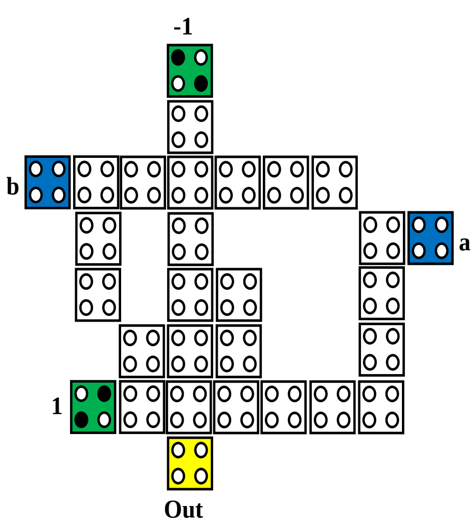
According to Fig. 9(e) and (f), A.N. Bahar et al. [12] with A. Chabi et al. [13] have reduced the number of cells until 12 cells and 14 cells, using respectively 0.0116 μm^2 and 0.01 μm^2 area, at the same clock zones latency of 0.5.



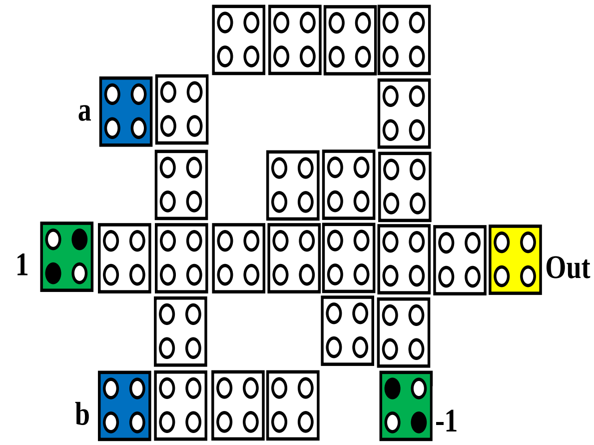
(a) [8]



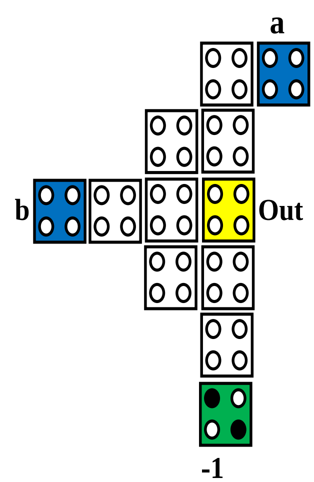
(b) [9]



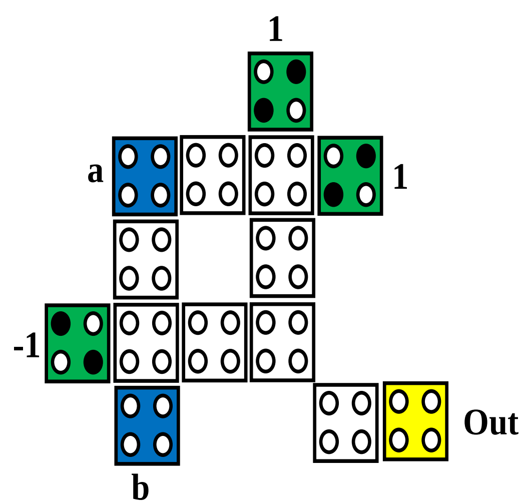
(c) [10]



(d) [11]



(e) [12]



(f) [13]

Fig. 9. The structure of two inputs “XOR” gate, (a) in [8]; (b) in [9]; (c) in [10] (d) in [11]; (e) In [12]; (f) in [13].

III. Different Architectures of Digital "XOR" Gate with QCA Implementation

A. Proposed Architecture of 2-Input Digital "XOR" Gate

The 2-input logical "XOR" gate is a hybrid circuit where its output combining between Inverter gate, "OR" gate, "AND" gate. The schematic of a simple digital "XOR" gate is presented in Fig. 10. This circuit has two inputs: "a" and "b", and one output "Out".

The truth table of this two-input "Exclusive-OR" gate is shown in Table 2.

From this table, it can be deduced that when "a" and "b" are different, the output "Out" is equal to "1", and when "a" and "b" are equal, the output "Out" is equal to "0". Hence the output "Out" of the "exclusive-OR" ("XOR") gate performs the following logic operation:

$$Out = a \oplus b = \overline{a}.b + a.\overline{b} \quad (4)$$

In this paper, a novel design of two-input "Exclusive-OR" using QCA implementation gate is proposed. It is defined by a small number of cells and high density. Then a new design of 4 inputs and 8 inputs logical "XOR" gate are designed by using the proposed architecture of 2-input digital "XOR" gate.

This novel design of two-input "XOR" gate is composed of two inputs "a", "b", and one fixed logic "0", with one output "Out". The structure and the QCA layout of the proposed QCA are shown in Fig. 11.

The simulation results of the proposed 2-input logical "XOR" gate are presented in Fig. 12. Two waveforms with different frequencies and colours are applied to the inputs (a, and b: represented by blue colour signals), the clock0 (represented by a red colour signal) and one waveform for the digital "XOR" gate outputs (Out: represented by a yellow colour signal). From Fig. 12, it can be deduced the latency of one a clock of the novel proposed "XOR" gate constituted by only 10 cells with an area of 0.008 μm^2.

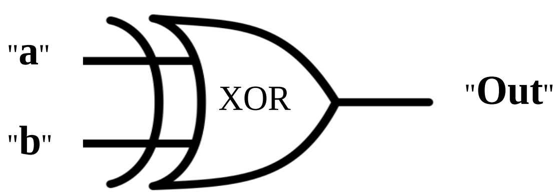


Fig. 10. Schematic of 2-input "XOR" gate.

TABLE II. Truth Table of 2-input "XOR" Gate

a	*b*	*Out*
0	0	0
0	1	1
1	0	1
1	1	0

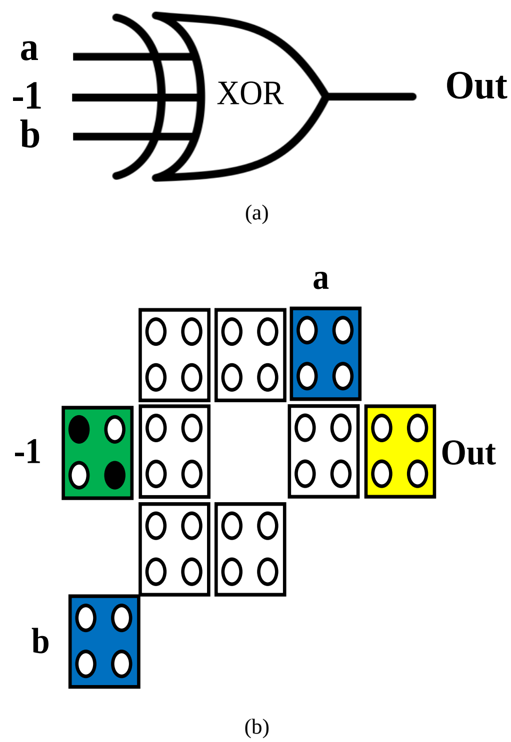


Fig. 11. The architecture of novel design "XOR" gate structure, (a)Schematic of "XOR" gate; (b) QCA layout of proposed "XOR" gate.

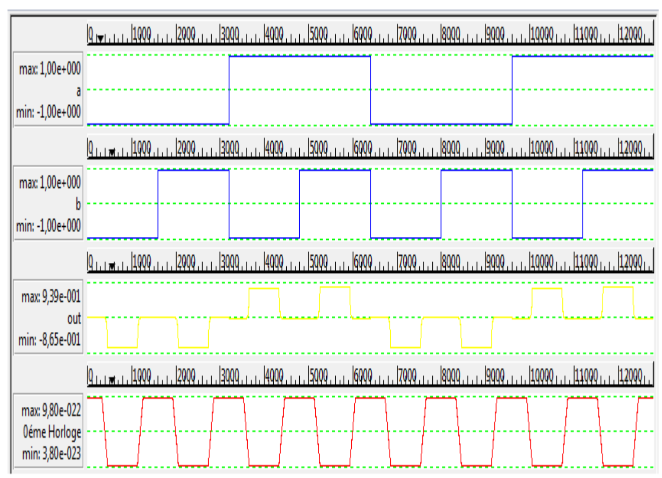


Fig. 12. The simulation result of the novel architecture of 2-input logical "XOR" gate.

B. Proposed Architecture of 4-Input Digital "XOR" Gate

The 4-input logical "XOR" gate is a combination between two elements of 2-input logical "XOR" gate. The schematic of this digital "XOR" gate is presented in Fig. 13. This circuit has four inputs: "a", "b", "c", "d", and one output "Out".

The truth table of this four-input "Exclusive-OR" gate is shown in Table 3.

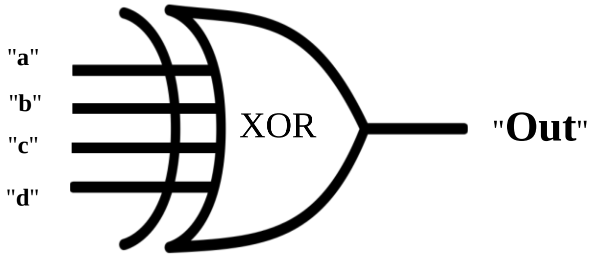


Fig. 13. Schematic of 4-input "XOR" gate.

TABLE III. TRUTH TABLE OF 4-INPUT "XOR" GATE

a	*b*	*c*	*d*	*Out*
0	0	0	0	0
0	0	0	1	1
0	0	1	0	1
0	0	1	1	0
0	1	0	0	1
0	1	0	1	0
0	1	1	0	0
0	1	1	1	1
1	0	0	0	1
1	0	0	1	0
1	0	1	0	0
1	0	1	1	1
1	1	0	0	0
1	1	0	1	1
1	1	1	0	1
1	1	1	1	0

From this table, it can be deduced that when the number of the input "1" is impaired, the output "Out" is equal to "1". In the case of the number of the input "1" is a pair, the output "Out" is equal to "0". Hence the output "Out" of the "exclusive-OR" ("XOR") gate can determine the parity and given by the following logic operation:

$$Out = a \oplus b \oplus c \oplus d \qquad (5)$$

A proposed architecture of 4-input "XOR" gate based on three blocks of 2-input "XOR" gate is composed of four inputs "a", "b", "c", "d", and three fixed logic "0", with one output "Out". The structure and the QCA layout of the proposed 4-input "XOR" gate are shown in Fig. 14.

According to Fig. 15, the simulation results of the proposed 4-input logical "XOR" gate are presented. Four waveforms with different frequencies and colors are applied to the inputs (a, b, c, and d: represented by blue color signals), the clock0 (red color signal) and one waveform for the digital 4-input "XOR" gate outputs (Out: yellow color signal). It can be interpreted that this "XOR" circuit is composed of 35 cells, the latency of six a clock, with an area of 0.036 µm^2.

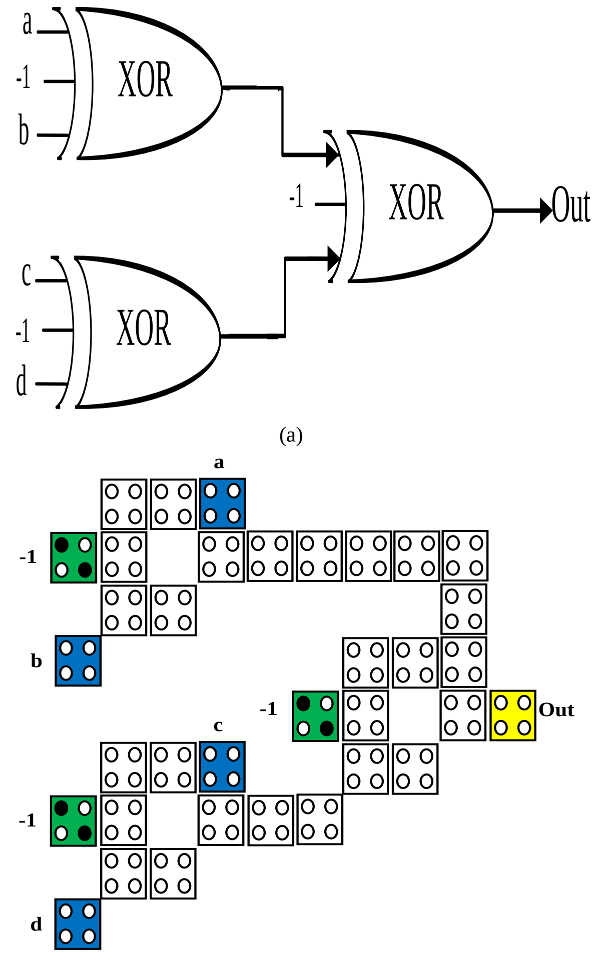


Fig. 14. The architecture of 4-input "XOR" gate, (a) Schematic; (b) QCA layout of proposed "XOR" gate.

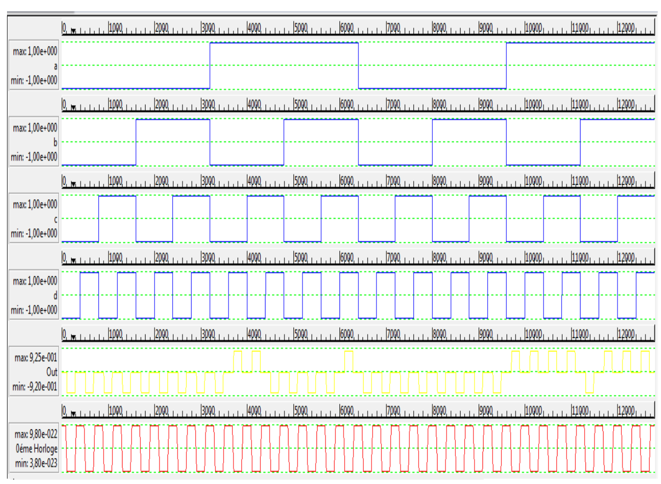


Fig. 15. The simulation result of the novel architecture of 4-input logical "XOR" gate.

C. Proposed Architecture of 8-Input Digital "XOR" Gate

The 8-input logical "XOR" gate is combined from two elements of 4-input logical "XOR" gate or four elements of 2-input logical "XOR" gate. The schematic of this 8-input "XOR" gate is constructed of eight-input: "a", "b", "c", "d", "e", "f", "g", "h", and one output "Out" as shown in Fig. 16.

The truth table of this eight-input "XOR" gate is shown in Table 4.

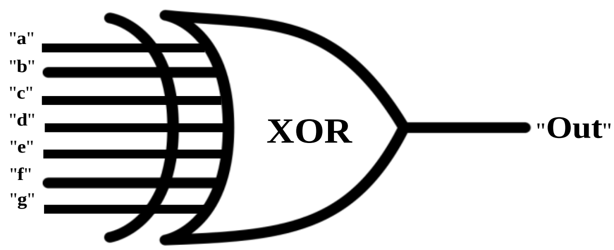


Fig. 16. Schematic of 8-input "XOR" gate.

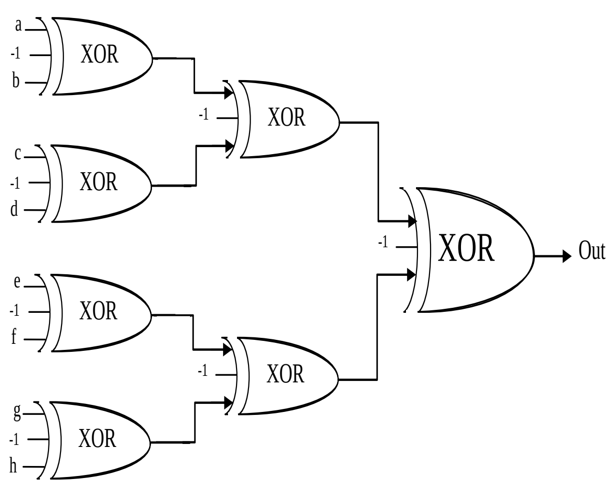
TABLE IV. TRUTH TABLE OF 8-INPUT "XOR" GATE

a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*Out*
0	0	0	0	0	0	0	0	0
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
1	1	1	1	1	1	1	1	0

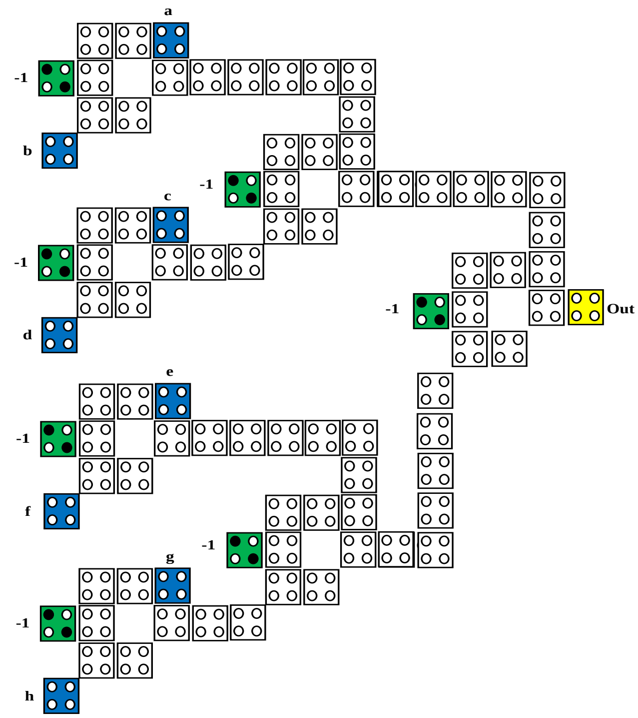
From this table, from the number of the inputs "1" is a pair or impair, the parity can be determined by the output. When "Out" = 1, the number of the inputs "1" is a pair, and when "Out" = 0, the number of the inputs "1" is impaired. Hence the output of 8-input "XOR" gate can be expressed as:

$$Out = a \oplus b \oplus c \oplus d \oplus e \oplus f \oplus g \oplus h \qquad (6)$$

A proposed structure of digital 8-input "XOR" gate based on seven block of 2-input "XOR" gate is composed of eight inputs "a", "b", "c", "d", "e", "f", "g", "h", and seven fixed logic "0", with one output "Out". The architecture and the QCA layout of the proposed 8-input "XOR" gate are presented in Fig. 17.



(a)



(b)

Fig. 17. The architecture of 8-input "XOR" gate, (a) Schematic; (b) QCA layout.

The simulation results of the proposed 8-input logical "XOR" gate are presented in Fig. 18. Eight waveforms with different frequencies and colours are applied to the inputs (a, b, c, d, e, f, g, and h: represented by blue color signals), the clock0 (Clk0: red colour signal) and one waveform for the 8-input digital "XOR" gate output (Out: yellow colour signal). From Fig. 18, the latency of 96 a clock is achieved by the proposed 8-input logical "XOR" gate, which is constituted of 90 cells with an area of 0.114 µm^2.

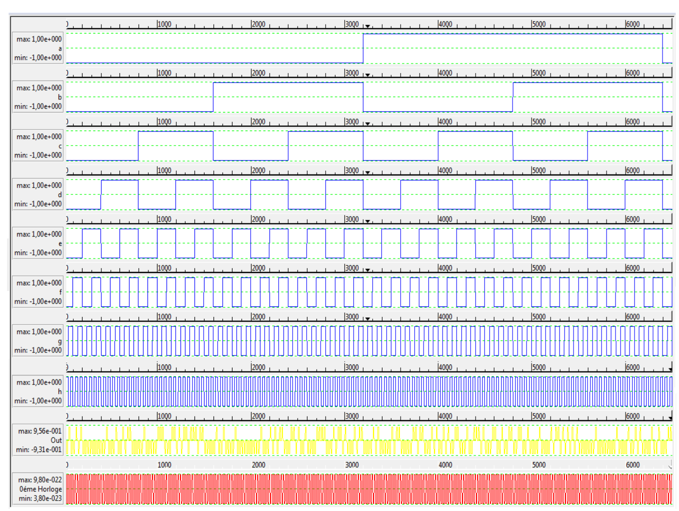


Fig. 18. The simulation result of the novel architecture of 8-input logical "XOR" gate.

IV. Analysis and Evaluation

The comparison between the proposed of 2-input digital "XOR" gate to the others architectures is given in Table 5. In this table complexity is given by the number of required cells, latency is given by the number of required clock zones, the area is given by μm^2, cell size is given by (nm) and Cross-over is either coplanar or multilayer or not required. Based on the proposed of 2-input digital "XOR" gate shown in Fig. 11, simulations results in Fig. 12 and comparative results in Table 5, the presented "XOR" gate has an improvement result in term of Complexity, and area compared with other architectures [8]-[13].

Based on the novel design of 4-input digital "XOR" implemented from 2-input digital "XOR" gate shown in Fig. 14, simulations results in Fig. 15 and comparative results in Table 6, the presented "XOR" gate has an improvement result in term of area, complexity and latency compared with other architectures [8]-[15].

Based on the novel design of 8-input digital "XOR" gate implemented from 4-input digital "XOR" gate and 2-input digital "XOR" gate shown in Fig. 17, simulations results in Fig. 18, and comparative results in Table 7, the presented 4 to 1 QCA multiplexer has an improvement result in term of area and complexity compared with other architectures [10], [11], [14], [15].

TABLE V. Comparison Results of the Presented 2-Input Digital "XOR" Gate

Structure	***Gate count***	***Area (μm^2)***	***Complexity***	***Latency (clock)***	***Cross-over type***	***Cell size (nm × nm)***
[8]	5	0.09	60	1.5	Coplanar (rotated cells)	18 × 18
[9]	5	0.08	54	1.5	Coplanar (rotated cells)	18 × 18
[10]	4	0.03	29	0.75	Not required	18 × 18
[14]	3	0.06	67	1.25	Coplanar	18 × 18
[15]	3	0.02	32	1	Not required	18 × 18
[11]	-	0.02	28	0.75	Coplanar	18 × 18
[12]	1	0.0116	12	0.5	Not required	18 × 18
[13]	-	0.01	14	0.5	Not required	18 × 18
The proposed	**-**	**0.008**	**10**	**1**	Coplanar	**18 × 18**

TABLE VI. Comparison Results of the Presented 4-Input Digital "XOR" Gate

Structure	***Gate count***	***Area (μm^2)***	***Complexity***	***Latency (clock)***	***Cross-over type***	***Cell size (nm × nm)***
[10]	12	0.19	106	1.75	Not required	18 × 18
[14]	9	0.2	188	2.25	Not required	18 × 18
[15]	9	0.11	98	2	Not required	18 × 18
[11]	-	0.1	87	1.75	Not required	18 × 18
The proposed	**-**	**0.036**	**35**	**6**	Coplanar	18 × 18

TABLE VII. Comparison results of the presented 8-input digital "XOR" gate

Structure	***Gate count***	***Area (μm^2)***	***Complexity***	***Latency (clock)***	***Cross-over type***	***Cell size (nm × nm)***
[10]	28	0.6	269	2.75	Not required	18 × 18
[14]	19	0.49	369	2.25	Not required	18 × 18
[15]	19	0.37	241	3	Not required	18 × 18
[11]	-	0.3	213	2.75	Not required	18 × 18
The proposed	-	**0.114**	**90**	-	**Coplanar**	**18 × 18**

V. Conclusion

This paper presented a novel and unique design of 2-input digital "XOR" gate in the QCA technology. This approach can achieve and implement 4-input and 8-input logical "XOR" gate by using the coplanar crossover technique. The simulations results are achieved by QCA Designer version 2.0.3. From these simulations, the proposed QCA multiplexer structure provides an improvement in terms of circuit complexity (10 cells), area (0.008 μm^2) and latency (1 clock) in comparison to other previous QCA multiplexer structures [8]-[13]. Different structures of 4-input and 8-input digital "XOR" gate are implemented from this 2-input digital "XOR" gate. These different digital "XOR" gates have the capability to be using in parity checking, detection and correction operations in the receiver and sender units. In addition, this architecture of "XOR" gate plays an important role in arithmetic and logical unit (ALU) of a processor. In the current proposed work, we have optimized the number of QCA cellule and reduced the wire-crossings. Further, this work may be extended to design other reversible QCA gates.

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Word-Based Grammars for PPM

Nojood O. Aljehane
College of Computers & Information Technology
University of Tabuk,
Tabuk, Saudi Arabia

William J. Teahan
Department of Computer Science
Bangor University
Bangor, United Kingdom

***Abstract*—The Prediction by Partial Matching (PPM) compression algorithm is considered one of the most efficient methods for compressing natural language text. Despite the advances of the PPM method for the English language to predict upcoming symbols or words, more research is required to devise better compression methods for other languages, such as Arabic due, for example, to the rich morphological nature of the Arabic text, where a word can take many different forms. In this paper, we propose a new method that achieves the best compression rates not only for Arabic text but also for other languages that use Arabic script in their writing system such as Persian. Our word-based method constructs a context-free grammar (CFG) for the text and this grammar is then encoded using PPM to achieve excellent compression rates.**

Keywords—Component; context-free grammar (CFG); grammar-base; word-based; Preprocessing; Prediction by Partial Matching (PPM); encoding

I. Introduction

The Prediction by Partial Matching (PPM) compression algorithm is one of the most effective kinds of statistical compression. First described by Cleary and Witten in 1984 [1], there are many variants of the basic algorithm, such as PPMA and PPMB [1], PPMC [2], PPMD [3], PPM [4], PPMZ [5] and PPMii [6]. Prediction in PPM depends on a bounded number of previous characters or symbols, effectively using a Markov-based approach. Despite the cost in terms of memory and the speed of execution, PPM usually attains better compression rates compared with other well-known compression methods.

In PPM, to predict the next character or symbol, different orders of models are used, starting from the highest order down to the lowest orders. An escape probability estimates if a new symbol appears in the context [1], [2] and if an escape is encoded, the algorithm will back-off to a lower order model. The 'full exclusions' mechanism [1] is used to significantly improve compression by excluding the prediction of higher order symbols when an escape has occurred since these characters were not encoded [17]. Experimental results show that not using full exclusions speeds up the execution time of programs but compression is reduced.

However, when a PPM approach is applied to words rather than characters, it is not clear what the most effective method for encoding the text is. This is because there are issues of how to encode the spaces and punctuation along with the text, how to deal with capitalized words, whether to treat digit sequences differently, how to deal with the much larger alphabet when using full exclusions, and so on. This is compounded further when considering certain languages, such as Arabic, which has a rich morphological structure which potentially presents further types of difficulties for word-based compression compared to languages, such as English since the same word can take many different forms.

As an illustration, the lists below in Table 1 show the most common words in each of the examined texts. They are based on an analysis of the Brown Corpus for American English [9], the LOB Corpus for British English [10], the BACC [11] and CCA [12] Corpora for Arabic text, the Hamshahri corpus for Persian text [13] and the CEG corpus for Welsh text [16].

Substitution of these words using our context-free grammar scheme and standard PPM can significantly improve overall compression as shown below. For example, natural languages contain common sequences of words that often repeat in the same order, such as in English "the" , "of" and "and", and for the Arabic language in the BACC corpus , such as "من", " في" and so on. From Table 1, the most common word "the" for both the American and British English is found to be "the". However, for these corpora if one treats capitalized words as being distinct (that is, "the" is treated as distinct from "The"), we find that the word "The" also appears in the top 20 ranked words, but at different ranks (12 for the Brown Corpus versus 16 for the LOB Corpus). In contrast, the word "had" appears with the same rank for both corpora. Certain words, such as "from" and "at" appear in the list for one corpus but not for the other.

TABLE I. THE TOP COMMON 20 WORDS FOR THE BROWN, LOB, BACC, CCA AND HAMSHAHRI TEXT CORPORA

Rank	**Brown Corpus**	**LOB Corpus**	**BACC Corpus**	**CCA Corpus**	**Hamshahri**
1	the	the	من	في	برورش
2	of	of	بن	من	دستور
3	and	and	قال	على	سمتى
4	to	a	الله	ان	اين
5	a	in	ما	إلى	حميد
6	in	that	بالله	التي	در
7	that	is	في	عن	اعلام
8	is	was	أبو	ما	بنيادى
9	was	for	محمد	لا	اظهارات
10	for	it	عليه	هذا	صف
11	with	to	على	هذه	كند
12	The	be	إلى	الذي	افزود
13	as	his	أن	أو	براى
14	he	as	علي	و	بر
15	it	on	عبد	كان	آول
16	his	The	عنه	مع	كردند
17	on	his	له	لم	كجا
18	be	at	ثم	كل	كه
19	from	as	لك	ذلك	كذشته
20	had	had	الذي	بين	اداره

For Arabic text, the most common word for both the BACC and ACC Corpora is found to be "في" (in). Nevertheless, we find that the word "ان" (that) also appears in the top 20 ranked words, but at different ranks (4 for the ACC Corpus versus 6 for the BACC Corpus). In contrast, the word "من" (from) appears with the same rank for both corpora. Certain words such as " التي" (which) and "له" (for him) appear in the list for one corpus but not for the other. For Persian text in the Hamshahri Corpus, even if it uses Arabic script, the top 20 ranked words are noticeably different due to the difference between these two languages.

From these lists, it is clear even just from examining the top 20 ranking words that there are important differences, and therefore word-based compression schemes have to adapt directly to the text being compressed in an online manner (as PPM does) rather than use dictionaries created from general sources. Another factor is that since the most frequent words represent a significant proportion of the text, adaptive word-based schemes can often lead to improved compression for many languages. An added advantage of such schemes is that much less symbols need to be encoded (for example, for English, there is on average approximately five times less word symbols than there are character symbols). However, finding the most effective word-based compression is still an open problem with word-based schemes under-researched compared to character-based schemes. The comparison between the effectiveness of word-based schemes with character-based and parts-of-speech (tags) based ones also provides an interesting tool for performing further linguistic analysis [8]. The main contribution of the work described in this paper is the improved word-based compression method for PPM. This is due to parsing of the text to construct a word-based context free grammar (CFG) which is then compressed using PPM.

The rest of the paper is organized as follows. Previous work is discussed first. Then our new approach is discussed in the next section. We discuss experimental results for various natural language texts in order to evaluate how well the new scheme performs compared to other well-known methods. The summary and conclusions are presented in the final section.

II. Previous Work

As stated, standard PPM word-based models predicts the forthcoming symbol, starting from the highest order context; but when the upcoming symbol has not appeared in this context then a lower context is used and an escape symbol is encoded. There have been a number of methods that have been used to estimate the probability for these escape symbols [7], [8].

Experiments indicate that the X1 method is the best performing for English text in the most cases [8]. This method is given by the formula:

$$\mathrm{e} = \frac{t_1+1}{T_d+t_1+1} \tag{1}$$

Here, t_1 denotes the number of symbols seen previously only once in the context and T_d is the frequency with which the symbol occurs in the context. Therefore, this method estimates the escape symbol probability proportionate to the number of words that have appeared only once in the text.

TABLE II. Some models for predicting characters and words (Teahan, 1998)

$C\|C^5$ Model	W|W Model
$p(c_i \mid c_{i-1}\, c_{i-2}\, c_{i-3}\, c_{i-4}\, c_{i-5})$	$p(w_i \mid w_{i-1})$
$\rightarrow p(c_i \mid c_{i-1}\, c_{i-2}\, c_{i-3}\, c_{i-4})$	$\rightarrow p(w_i)$
$\rightarrow p(c_i \mid c_{i-1}\, c_{i-2}\, c_{i-3})$	→ *Character model*
$\rightarrow p(c_i \mid c_{i-1}\, c_{i-2})$	
$\rightarrow p(c_i \mid c_{i-1})$	
$\rightarrow p(c_i)$	
$\rightarrow p_e\, q(c_i)$	

Experiments for the English language show that word based models in Table 2 presents the best performance among other models [8].

Model $C|C^5$ is a PPM character model of order five that predicts the probability of character symbols and used as a compression baseline. In this model, the formula for the probability of text string *S* of *m* characters is given by:

$$p(S) = \prod_{i=1}^{m} p(c_i \mid c_{i-1}\; c_{i-2}\; c_{i-3}\; c_{i-4}\; c_{i-5}) \tag{2}$$

Where, the preceding five characters in the text is used to estimate the probability of the forthcoming symbol.

This estimate of the probability for the previous formula depends on the escape method (in Table 2, the symbol → denotes an escape). In character based models, if the highest order fails to predict forthcoming symbol, the probability of escape is encoded using the next highest order.

The second model W|W, is a PPM order one word-based model that predicts the probability of word symbols. In this model, the estimation of the probability for the forthcoming word depends on the previous word in the text as represented by the following formula for the probability of text string *S* of *n* words:

$$p(S) = \prod_{i=1}^{n} p(w_i \mid w_{i-1}) \tag{3}$$

Where, *p* denotes the probability of the symbols in the sequence of the text *S* based on words. If the word is not predicted by this model, then an escape is encoded down to the order 0 model. If the word still has not been seen in this context, then a further escape is encoded followed by each character in the word being encoded separately using the standard PPM character-based model.

III. Word-Based Grammars for PPM (GRW-PPM)

A new approach based on word-based context free grammars (CFGs) for compressing text files is presented here. This algorithm, which we call GRW-PPM (which is short for grammar word-based pre-processing for PPM) uses both CFGs and PPM as the basis of a universal general-purpose adaptive compression method for text files.

In our approach, we essentially parse words, digits, spaces and punctuation in the source file to first generate a grammar with rules and terminal and non-terminal symbols representing each of these text elements. We then substitute every time when one of these text elements occurs in the source text with the single unique non-terminal symbol as specified by its rule in the grammar. This is done during the pre-processing phase prior to the PPM compression phase which is applied to the sequences of non-terminal symbols for words, digits and spaces and punctuation separately.

Our method replaces sequences of words (n-grams) in the text as they are processed from beginning to end in a single pre-processing pass. The PPM algorithm is used as the encoder once the sequences have been replaced. Unlike PPM, our method is off-line during the phase which generates the grammar.

Our approach adapts the W|W word-based method and the character n-graph replacement pre-processing approach of Teahan [8] by using an off-line technique to generate the list of word n-grams first from the source file being compressed. However, our approach is considered within a grammar-based context instead. The main difference with the prior word-based schemes (such as W|W) is the use of PPM to encode the sequence of word symbols directly without the need to escape to a separate character-level encoding and also treatment of digits as word symbols (see below).

The grammar in GRW-PPM shares the same characteristic as Sequitur by Neville-Manning and Witten [14] and GR-PPM [15] which is that no pair of symbols appears in the grammar more than once. This property ensures that every n-gram in the grammar is unique, a property called non-terminal uniqueness using the same terminology proposed by Neville-Manning and Witten. To make sure that each rule in the grammar is useful, the second property, referred to as rule utility, is that every rule in the grammar is used more than once in the corrected text sequence.

Fig. 1 shows the whole process of GRW-PPM. First, the original text will be parsed and word, digit and space/punctuation tokens will be extracted then the CFG will be generated by replacing them in the text wherever they occur with the non-terminal symbols as defined by their rules in the grammar. After the rules have been produced, the grammar is encoded by using PPMD, and the resulting compressed text is then sent to the receiver. The receiver then decodes the grammar by using PPMD to decompress the compressed file that was sent. The reverse mapping is then facilitated by using the decoded grammar to regenerate the original source text.

Table 3 illustrates the process of GRW-PPM using a sentence referring to the song by Manfred Mann: "*The song 'Do Wah Diddy Diddy Dum Diddy Do' was recorded on 11 June 1964 and released on 10 July*". First, the original text will be parsed from left to right and new non-terminal word and digit symbols (S_1 S_2 S_3 S_4 S_5 S_5 S_6 S_5 … S_{12} S_9 D_3 S_{13}) will be substituted for each unique n-gram (defined as being separated by the intervening space and punctuation symbols). For this example (and for the experiments described below), we use single words (unigrams), although the method works in a similar way for word bigrams and trigrams. Referring to Table 3, we replace the unigram "The" with non-terminal symbol S_1, unigram "song" with non-terminal symbol S_2, unigram "Do" with non-terminal symbol S_3 and so on. We use bullet points for spaces to make them visible. Spaces (white-space) and punctuation define the word boundaries (i.e. each word is made up of sequences of anything that is not white-space or punctuation).

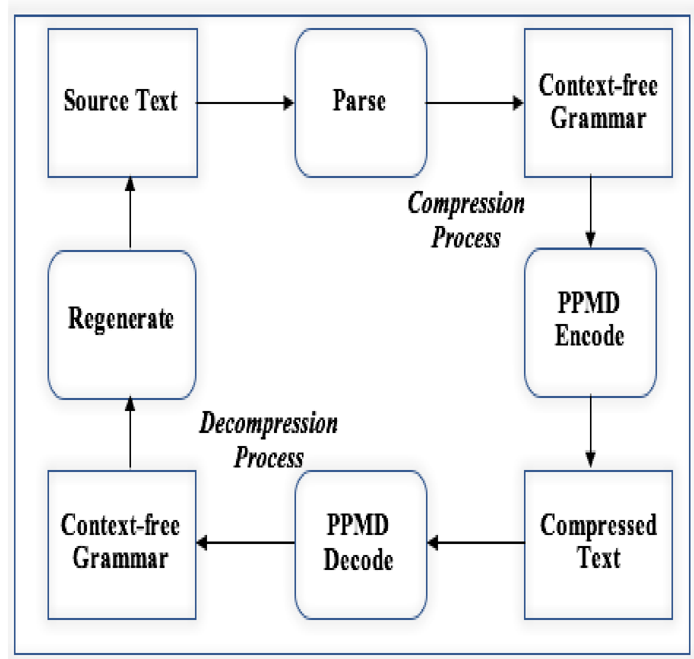

Fig. 1. The complete compression and decompression process of GRW-PPM.

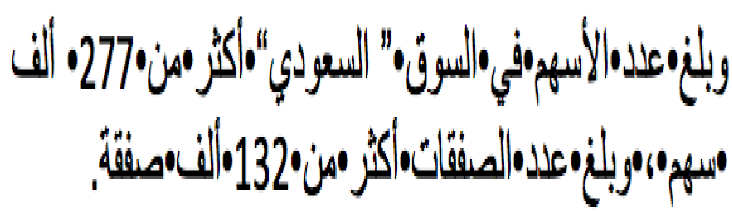

Fig. 2. Example of Arabic text.

TABLE III. AN EXAMPLE OF HOW GRW-PPM WORKS FOR A SAMPLE ENGLISH TEXT

Sequence:	
The•song•"Do•Wah•Diddy•Diddy•Dum•Diddy•Do"•was•recorded•on•11•June •1964•and•released•on•10•July.	
Grammar:	
$S \rightarrow S_1\ S_2\ S_3\ S_4\ S_5\ S_5\ S_6\ S_5\ S_3\ S_7\ S_8\ S_9\ S_D\ S_{10}\ S_D\ S_{11}\ S_{12}\ S_9\ S_D\ S_{13}$	$S_8 \rightarrow$ "recorded"
$V \rightarrow S_1\ S_2\ S_3\ S_4\ S_5\ S_6\ S_7\ S_8\ S_9\ S_{10}\ S_{11}\ S_{12}\ S_{13}$	$S_9 \rightarrow$ "on"
$D \rightarrow D_1\ D_2\ D_3$	$S_{10} \rightarrow$ "June"
$P \rightarrow P_1\ P_2\ P_1\ P_1\ P_1\ P_1\ P_1\ P_1\ P_3\ P_1\ P_1\ P_1\ P_1\ P_1\ P_1\ P_1\ P_1\ P_1\ P_1\ P_4$	$S_{11} \rightarrow$ "and"
$S_1 \rightarrow$ "The"	$S_{12} \rightarrow$ "released"
$S_2 \rightarrow$ "song"	$S_{13} \rightarrow$ "July"
$S_3 \rightarrow$ "Do"	$D_1 \rightarrow$ "11"
$S_4 \rightarrow$ "Wah"	$D_2 \rightarrow$ "1964"
$S_5 \rightarrow$ "Diddy"	$D_3 \rightarrow$ "10"
$S_6 \rightarrow$ "Dum"	$P_1 \rightarrow$ "•"
$S_7 \rightarrow$ "was"	$P_2 \rightarrow$ "•""
	$P_3 \rightarrow$ ""•"
	$P_4 \rightarrow$ "."

Table 4 shows the same process for a sample Arabic text (Fig. 2) which translates into English as follows: “The number of shares traded in the market, ‘Saudi’ were more than 277 thousand shares, and the number of transactions were more than 132 thousand transactions.” However, in this case the n-grams are generated from right to left instead. Each unique Arabic unigram has a non-terminal symbol associated with it. For instance, words “وبلغ”, “عدد” and “الأسهم” are replaced by non-terminal symbols S_1 to S_3, respectively.

In the grammar examples, the S rule is used to represent the word and digit symbols sequence. Separate rules (S_1, S_2, S_3 …) are used, one for each word, to specify each symbol’s contents directly using a non-terminal (denoted by characters surrounded by “ ’s). The V rule enumerates each of these words in order; it is used to represent the vocabulary (the sequence of unique words as they occur in the text). Each digit sequence is encoded within the S sequence by using a special symbol to indicate the positions of the digits in the sequence (as represented by S_D in the above examples). The actual contents of each digit symbol is specified by the D rule and encoded separately to the word and digit symbols. We also process spaces and any punctuation characters in order to be able to fully decode the original text back. These are represented by the P rules for the grammars in the above examples and are similarly encoded separately to the word and digit unigram symbols. Moreover, the grammar will be transmitted to the receiver once it has been constructed after all unigrams are substituted in the original text with their non-terminal symbols.

The grammar represents a complete description of the text and therefore it is possible to devise a lossless text compression scheme by directly encoding it in some manner since it is possible for the decoder to regenerate the complete source text losslessly once the grammar has been decoded.

TABLE IV. ANOTHER EXAMPLE GRAMMAR GENERATED BY GRW-PPM FOR A SAMPLE ARABIC TEXT

Sequence: وبلغ•عدد•الأسهم•في•السوق•"السعودي"•أكثر•من•277• ألف •سهم•وبلغ•عدد•الصفقات•أكثر•من•132•ألف•صفقة.	
Grammar:	
$S \rightarrow S_1\ S_2\ S_3\ S_4\ S_5\ S_6\ S_7\ S_3\ S_7\ S_8\ S_D\ S_9\ S_{10}\ S_1\ S_2\ S_{11}\ S_7\ S_8\ S_D\ S_9\ S_{12}$	$S_8 \rightarrow$ “من”
$V \rightarrow S_1\ S_2\ S_3\ S_4\ S_5\ S_6\ S_7\ S_8\ S_9\ S_{10}\ S_{11}\ S_{12}$	$S_9 \rightarrow$ “ألف”
$D \rightarrow D_1\ D_2\ D_3$	$S_{10} \rightarrow$ “سهم”
$P \rightarrow P_1\ P_1\ P_1\ P_1\ P_2\ P_3\ P_1\ P_1\ P_1\ P_1\ P_1\ P_1\ P_1\ P_1\ P_1\ P_1\ P_1\ P_1\ P_4$	$S_{11} \rightarrow$ “الصفقات”
$S_1 \rightarrow$ “وبلغ ”	$S_{12} \rightarrow$ “صفقة”
$S_2 \rightarrow$ “عدد”	$D_1 \rightarrow$ “277”
$S_3 \rightarrow$ “الأسهم”	$D_2 \rightarrow$ “132”
$S_4 \rightarrow$ “في”	$P_1 \rightarrow$ “•”
$S_5 \rightarrow$ “السوق”	$P_2 \rightarrow$ ““•”
$S_6 \rightarrow$ “السعودي”	$P_3 \rightarrow$ “•””
$S_7 \rightarrow$ “أكثر”	$P_4 \rightarrow$ “."

As stated, we have found one effective means for encoding the grammar is to use PPM. Specifically, the grammar is encoded by using PPMD to separately encode the four main elements (words, vocabulary, digits and spaces/punctuation as represented by the S, V, D and P rules). For Rule S, we can encode the sequence of symbol numbers or letters that appear in the rule. For example, in Table 3, the sequence of symbol numbers/letters for Rule S is as follows: 1 2 3 4 5 5 6 5 3 7 8 9 D 10 D 11 12 9 D 13. This represents the sequence of id numbers assigned to each unique word with id numbers starting from 1 and incrementing by one whenever a new word is encountered. The letter D indicates when a digit sequence has occurred. Clearly, the sequence for rule S will be highly repetitive for long sequences of natural language text because of the presence of repeated words and frequent function words (such as “*the*” and “*and*” for English and “*من*” and “ في” for Arabic as shown in Table 1). More specifically, we have found PPMD to be very effective at encoding this sequence.

However, unlike W|W (which uses similar PPM-like methods to encode word symbols in this manner), our method simply uses PPMD with a fixed maximum alphabet size (since this is known when the grammar has been fully constructed for the whole text). Also, our method does not need to encode an escape down to a separate character-level as W|W does in order to encode novel words when they occur.

Instead, it uses the standard PPMD encoding mechanism (where a novel symbol will be encoded using a default order -1 model where all symbols are equiprobable).

For practical purposes, rule V and rules S_1, S_2, S_3, … can simply be represented as a string of text that contains all the unique words as they appear in the source text one after another with a separator (such as a space character) used to indicate the end of the previous word and the beginning of the next one. Similarly, we can use the same encoding technique for the digit sequences for rule D and rules D_1,D_2,D_3,… and for the spaces and punctuation for rule P and rules P_1,P_2,P_3,…. That is, both the digits and punctuation can be encoded effectively by using PPMD to encode one text string that contains all the unique digit sequences and another text string that contains the unique space and punctuation sequences respectively. A space character can be used as a separator for the digits, but for the punctuation, a different separator is needed. We use the letter “W” as the separator in this case to mark where the words are.

As an illustration, Table 5 presents the symbols or text that is being encoded for the four elements (symbols, vocabulary, digits, spaces and punctuation) for the beginning of the Brown corpus. All are encoded directly by PPMD as text except for the Symbols element which is treated as a sequence of numbers instead.

The decompression process first uses PPMD to decode the four separate elements and then re-constructs the full grammar from them. During the subsequent regeneration phase, the grammar is then used to exactly regenerate the original source text character for character (i.e. the method is completely lossless). Whenever a previously unseen symbol is encountered as the sequence specified by the S rule is being processed, the current word is read from the sequence specified by the V rule and then the position is moved along to the next word.

TABLE V. WHAT THE DIFFERENT TEXT ELEMENTS LOOK LIKE FOR THE BEGINNING OF THE BROWN CORPUS

Brown Corpus (text at the start of the corpus): The Fulton County Grand Jury said Friday an investigation of Atlanta's recent primary election produced "no evidence" that any irregularities took place. The jury further said in term-end presentments that the City Executive Committee, which had over-all …			
Symbols	**Vocabulary**	**Digits**	**Spaces & Punctuation**
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 2 25 26 7 27 28 29 30 20 31 32 33 34 35 36 37 38 39 11 31 16 40 31 41 42 43 11 31 32 11 12 44 31 45 27 35 31 16 46 47 2 48 49 28 25 36 50 51 52 3 53 54 55 56 57 58 59 60 11 61 …	The Fulton County Grand Jury said Friday an investigation of Atlanta s recent primary election produced no evidence that any irregularities took place jury further in term end presentments the City Executive Committee which had over all charge …	1 1 2 2 1913 71 74 637 1937 1923 1 13 1962 8 1961 100 30 3 4 1958 50 10 87 31 29 5 13 1 119 402 18 17 63 31 300 000 6 13 451 500 157 460 88 000 182 17 000 1 000 12 3 81 65 4 22 1 4 250 114 4 5 000 000 15 000 000 24 12 30 24 4 150 13 1961 62 10 …	W W W W W W W W W W W'W W W W W "W W" W W W W W. W W W W W W-W W W W W W W, W W W-W W W W W, "W W W W W W W W W W" W W W W W W W W W. W W-W W W W W W W W W W W W W W W W W W "W" W W W-W W W W W W W-W W W W&. "W W W W W W W W W", W W W, "W W W W W W W, W W W W W W W W W W". W W W W W W W…

The P rule is used to insert the punctuation between the word and digit symbols as they are encountered in the S rule. Whenever a digit is signified by the S_D symbol for this rule, the current digit symbol is read from the sequence specified by the D rule, which is then inserted into the decoded output sequence and the position then moves along to the next digit symbol.

Algorithm 1 summarizes the algorithm using pseudo-code. Lines 1 through 15 are for the n-gram tokenizer. Line 3 starts the **for** loop to read the n-grams in the input file. Lines 4 through 9 check if the n-gram is a word; if it is, it prints the n-gram to the Grammar file, assigns each id numbers with ids for unique n-grams increasing with each new n-gram that is found and also prints a W to the Spaces & Punctuation file. Lines 10 through 13 checks if this n-gram is a digit; if it is, it adds this digit to the digit file and prints W to the Spaces & punctuation file. Lines 14 and 15 checks if this n-gram is punctuation or space; if so these are added to the Spaces & Punctuation file. Line 16 compresses the final text for the four files by using PPMD.

Algorithm 1: Pseudo-code for the GRW-PPM.

```
Input: The source text file
Output: Compressed text

1  Open Grammar, SYMBOLS, DIGITS and SPACES &
   PUNC. files
2  id ← 2
3  for each n-gram in input file do
4      if ngram is a new word then
5          print n-gram to Grammars file
6          Assign id to each n-gram
7          print id to SYMBOLS file
8          print W to SPACES & PUNC. file
9          id ← id + 1
10     else if n-gram is a digit then
11         print n-gram to DIGITS file
12         print number 1 to SYMBOLS file
13         print W to SPACES & PUNC. file
14     else
15         print n-gram to SPACES & PUNC. file
16 Use PPMD to encode the four files.
```

A further improvement of our approach, both in terms of compression and execution speed, can be gained by further processing the files in the following manner. The main disadvantage of the Symbols file is that it consists of many singletons that occur only once in the text and doubletons that occurs only twice [18]. Singletons and doubletons are detrimental to the encoding efficiency because they do not give any useful reference information [19]. In addition, singletons incur an unnecessary extra cost in our scheme because their symbol numbers are unique and therefore cause the alphabet size to be incremented by 1 each time they occur (which is frequently due to the Zipf's Law-like nature of natural language text). As a result, the alphabet size can be substantially higher when these are present. A large alphabet for PPM is undesirable when using the full exclusions mechanism [1] that PPM uses for its encoding as it substantially slows down execution speeds due to the need to exclude symbols already seen in the higher orders from lower order predictions.

In order to overcome these problems and therefore improve our new method, we process the Symbols file to replace all singletons in the Symbols file with the same special symbol wherever they occur. For example, for the Symbols stream "1 6 7 6 7 7 4 5" there are three singletons – 1, 4 and 5. These singletons get replaced by a special symbol (Φ, say) and the Symbols sequence being encoded becomes "Φ 6 7 6 7 7 Φ Φ'. Each singleton can be readily decoded once the special symbol is encountered in the Symbols stream which signals to the decoder to read the characters for the word from the next set of characters in the Vocabulary stream up until the next word separator character. For our example, let's say that the characters in the Vocabulary stream are "*one six seven four five*". When replacing just singletons in the Symbols stream, there is no need to change this Vocabulary stream since the decoder will have all the necessary information to decode each word since singletons only occur once. The only effect is that the Symbols stream becomes slightly more compressible with a much smaller alphabet which significantly speeds up compression speeds when performing full exclusions as shown below.

We also have an option to replace doubletons and tripletons (and so on) wherever they occur in the Symbols file if we wish. However, when replacing non-singletons in this case, there is no way to decode the characters when the word is being replaced the second time or subsequent times (for tripletons etc.) so a simple expedient is to repeat the word character for character in the Vocabulary stream whenever it occurs again. Using the previous example again, if we were to replace singletons and doubletons (but not tripletons), then the Symbols sequence would now be encoded as "Φ Φ 7 Φ 7 7 Φ Φ" since the symbol 6 appears twice (i.e. it is a doubleton) but symbol 7 appears three times (i.e. it is not a singleton or doubelton). In the Vocabulary stream in this case, the characters for symbol 6 would appear twice, i.e. it would now become "*one six seven six four five*" since the word "*six*" is a doubleton and therefore appears again in this sequence. Clearly, the size of the Vocabulary stream now will grow because of the presence of the repeated words and this can affect the overall compression, but this is offset by the significantly faster processing since the alphabet size in the Symbols stream is much smaller.

In the experimental results below, we use the following labels for the variants of our algorithm: GRW-PPM for our standard algorithm; GRW1-PPM for when singletons are replaced by the special symbol; GRW2-PPM for when both singletons and doubletons are replaced; GRW3-PPM for when all the singletons, doubletons and tripletons are replaced; and GRW4-PPM for when all the singletons, doubletons, tripletons and quadrupletons are replaced.

IV. Experimental Results

This section discusses experimental results using GRW-PPM and its variants described above for compression of various text files. We compare our new method with other compression schemes. Also, we discuss in this section the encoding execution times for GRW-PPM with and without using the full exclusions mechanism that PPM uses for its encoding.

In this experiment, the GRW-PPM encoding is divided into four parts. The four parts are for the Grammar, the Symbols, the Digits and the Spaces and Punctuation. Order 5 PPMD is used for the Grammar, order 1 PPMD for the Symbols, order 4 PPMD for the Digits and for Spaces and Punctuation, order 4 PPMD is used. Experiments showed these different orders were the most effective at compressing the different text elements.

Table 6 illustrates the compression ratio for the four parts. The compression ratio is calculated by multiplying the compressed output size in bytes times 8 divided by the original input file size in order to determine the contribution each part has to the overall encoding cost. As shown in the table, the Digits part has the smallest compression rate for the different languages. Also, the compression rate for Grammar and Spaces and Punctuation are small compared to the Symbols part for the Brown, LOB, CEG, Hamshahri and BACC corpora.

As shown in Table 7, order 1 GRW3-PPM significantly outperforms order 1 GRW-PPM as it has the best compression ratio for the corpora being compressed. The improvement of GRW3-PPM over GRW-PPM occurs for all texts and ranges from over 2% to 4.2% for the BACC corpus of Arabic text.

From our experiments as shown in Tables 7 and 10 for different text files, we found that full exclusions improves the compression rate. However, this increases the execution time slightly because for full exclusions all symbols are removed for prediction in the lower order level if they have already been seen in the higher order. (There may be many symbols needing to be excluded depending on the context.) The configuration of our test machine is 4 GB GHz intel Core i5, with 4GB internal memory.

It is clear from Tables 8 and 9 that not using full exclusions result in a worse compression rate. The improvement of GRW1-PPM and GRW2-PPM with full exclusions over GRW1-PPM and GRW2-PPM without using full exclusion ranges on average from just over 4% to 5.4% for all texts. However, the advantage in not performing full exclusions is that this runs on average 3% to 20% more quickly for different texts.

Table 11 shows an interesting result when comparing GRW-PPM and GRW3-PPM with PPMD and W|W. It is clear that GRW3-PPM on average significantly outperforms W|W. GRW3-PPM shows an average 7.1% improvement over W|W. Also, it illustrates that there are significant differences between each of the compression methods for different languages.

TABLE VI. Compression Ratios for GRW-PPM In The Four Elements For the Different Sample Texts

File	**Language or Dialect**	**Size**	**Symbols (bpc)**	**Vocabulary (bpc)**	**Digits (bpc)**	**Spaces & Punct. (bpc)**	**Overall (bpc)**
Brown	American English	5968707	1.698	0.226	0.014	0.278	2.21
LOB	British English	6085270	1.628	0.217	0.016	0.191	2.05
BACC	Arabic	31018167	1.078	0.143	0.006	0.173	1.40
Hamsh.	Persian	1120834	0.982	0.311	0.042	0.101	1.43
CEG	Welsh	6753317	1.284	0.147	0.089	0.214	1.73

TABLE VII. COMPRESSION RATIOS FOR GRW-PPM WITH FULL EXCLUSIONS COMPARED WITH GRW1-PPM, GRW2-PPM AND GRW3-PPM PERFORMANCE FOR DIFFERENT NATURAL LANGUAGES

File	GRW-PPM (bpc)	GRW1-PPM (bpc)	GRW2-PPM (bpc)	GRW3-PPM (bpc)	GRW4-PPM (bpc)
Brown	2.21	2.16	2.15	**2.14**	**2.14**
LOB	2.03	1.99	**1.98**	**1.98**	**1.98**
BACC	1.40	1.35	**1.34**	**1.34**	**1.34**
Hamsh.	1.43	1.41	1.40	**1.39**	**1.39**
CEG	1.73	1.70	**1.69**	**1.69**	**1.69**
Average	1.76	1.72	**1.71**	**1.71**	**1.71**

TABLE VIII. GRW-PPM WITHOUT FULL EXCLUSIONS COMPARED WITH GRW1-PPM, GRW2-PPM AND GRW3-PPM PERFORMANCE FOR DIFFERENT NATURAL LANGUAGES

File	GRW-PPM (bpc)	GRW1-PPM (bpc)	GRW2-PPM (bpc)	GRW3-PPM (bpc)	GRW4-PPM (bpc)
Brown	2.35	2.33	2.23	2.23	2.23
LOB	2.14	2.11	2.07	2.06	2.06
BACC	1.49	1.45	1.43	1.43	1.43
Hamsh.	1.52	1.48	1.46	1.46	1.46
CEG	1.80	1.76	1.76	1.75	1.75
Average	1.86	1.82	1.79	1.79	1.79

TABLE IX. EXECUTION TIMES FOR GRW1-PPM, GRW2-PPM, AND GRW3-PPM WHEN NOT USING FULL EXCLUSIONS

File	GRW1-PPM (seconds)	GRW2-PPM (seconds)	GRW3-PPM (seconds)	GRW4-PPM (seconds)
Brown	722.25	481.15	389.04	320.10
LOB	596.83	583.66	353.13	296.02
BACC	5655.20	4156.35	2339.16	3179.45
Hamsh.	2544.21	1375.30	965.34	843.35
CEG	275.82	198.56	193.31	138.03

TABLE X. EXECUTION TIMES FOR GRW1-PPM, GRW2-PPM, AND GRW3-PPM WHEN USING FULL EXCLUSIONS

File	GRW1-PPM (seconds)	GRW2-PPM (seconds)	GRW3-PPM (seconds)	GRW4-PPM (seconds)
Brown	760.83	600.05	471.92	342.59
LOB	670.20	436.98	328.12	329.57
BACC	6149.99	5292.56	3693.99	3320.88
Hamsh.	3260.91	2062.56	1268.33	916.22
CEG	302.71	264.58	239.56	173.57

TABLE XI. COMPARING THE PERFORMANCE OF THE PPMD, PPM WORD-BASED, GRW-PPM AND GRW3-PPM MODELS

File	Size	PPMD Order4 (bpc)	W|W Order4 (bpc)	GRW-PPM Order1 (bpc)	GRW3-PPM Order1 (bpc)
Brown	5968707	2.22	**2.13**	2.21	2.14
LOB	6085270	2.03	**1.96**	2.05	1.98
BACC	31018167	1.57	1.59	1.40	**1.34**
Hamsh.	1120834	1.75	1.79	1.43	**1.39**
CEG	6753317	**1.69**	1.70	1.73	**1.69**
Avg.		1.85	1.83	1.76	**1.70**

For instance, for American English text, W|W achieves the best compression rate compared with other models, with a 3.6% improvement over GRW-PPM and a 0.45% improvement over GRW3-PPM. For British English text, W|W achieves a 4.3% improvement over GRW-PPM and a 1.0% improvement over GRW3-PPM. For Welsh, GRW3-PPM and PPMD attain a 2.3% improvement over GRW-PPM and approximately a 1.0% improvement over W|W. For Arabic text, GRW3-PPM outperforms the other models, attaining a 14.6% improvement over PPMD and a 15.7% significant improvement over W|W. For Persian text, GRW3-PPM exceeds the other models, with a 22.3% improvement over W|W (see Fig. 3).

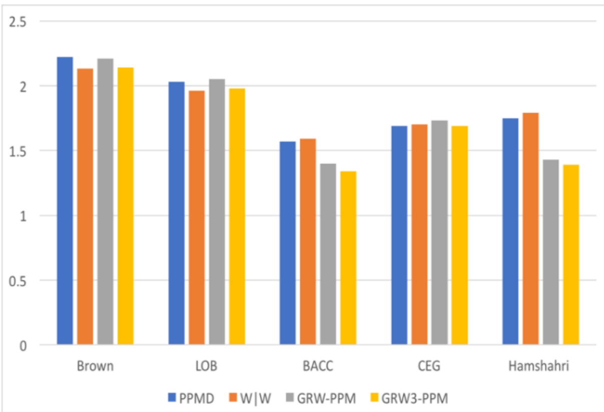

Fig. 3. Comparing the compression performance between the various methods for different languages.

V. Conclusions

In this paper, a new word-based grammar scheme (GRW-PPM) has been described for compressing natural language text. Our method creates a context-free grammar by replacing words and repeated sequences of digits, spaces and punctuation represented as non-terminal symbols in the text as it is processed from beginning to end in a single pre-processing pass. The PPM text compression algorithm is then used as the compression algorithm to encode the sequences of non-terminal sequences once they have been constructed for the whole text. Unlike PPM which is an online method, our method is off-line during the phase which generates the grammar.

In our experimental evaluation, GRW-PPM (and further such as variants GRW2-PPM and GRW3-PPM) have been compared with other well-known schemes on various language corpora for the English, Welsh, Arabic and Persian languages. The best performing scheme for the languages that use Arabic script (Arabic and Persian) is GRW3-PPM, followed by the previous best performing word-based PPM models (W|W) then the standard character-based PPMD scheme. For the English language, our experiments show that the word-based PPM models (W|W) is the best compared with standard PPM and GRW-PPM. For Welsh text, the best results are achieved using the standard character-based PPMD scheme and GRW3-PPM. Also, GRW3-PPM significantly outperforms GRW-PPM itself for different languages.

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Sentiment Summerization and Analysis of Sindhi Text

Mazhar Ali[1],[2]
[1]Shaheed Zulifqar Ali Bhutto Institute of Science and Technology (SZABIST), Karachi,
[2]Benazir Bhutto Shaheed University, Karachi,
Sindh Pakistan

Asim Imdad Wagan[3]
[3]Mohammad Ali Jinnah University Karachi,
Sindh Pakistan

***Abstract*—Text corpus is important for assessment of language features and variation analysis. Machine learning techniques identify the language terms, features, text structures and sentiment from linguistic corpus. Sindhi language is one of the oldest languages of the world having proper script and complete grammar. Sindhi is remained less resourced language computationally even in this digital era. Viewing this problem of Sindhi language, Sindhi NLP toolkit is developed to solve the Sindhi NLP and computational linguistics problems. Therefore, this research work may be an addition to NLP. This research study has developed an own Sindhi sentimentally structured and analyzed corpus on the basis of accumulated results of Sindhi sentiment analysis tool. Corpus is normalized and analyzed for language features and variation analysis using DTM and TF-IDF techniques. DTM and TF-IDF analysis is performed using n-gram model. The supervised machine learning model is formulated using SVMs and K-NN techniques to perform analysis on Sindhi sentiment analysis corpus dataset. Precision, recall and f-score show better performance of machine learning technique than other techniques. Cross validation techniques is used with 10 folds to validate and evaluate data set randomly for supervised machine learning analysis. Research study opens doors for linguists, data analysts and decision makers to work more for sentiment summarization and visual tracking.**

Keywords*—Sindhi NLP; sentiment structurization; sentiment analysis; supervised analysis

I. INTRODUCTION

Supervised classification is important and noteworthy technique of data mining [1], [2] to analyse the text. The supervised classification model works on basis of training and test sets. Training set is used to train the model whereas test set is processed to evaluate the model performance. This research study has developed supervised machine learning model using SVMs. Random Forest and k-NN techniques to identify the true and false classified data from Sindhi structured and sentimental text corpus. Sindhi text corpus is annotated with NLP features therefore, it is multi-class text corpus. The corpus is constructed on basis of accumulated results of Sindhi NLP tool for Sindhi text sentiment analysis. The NLP toolkit is developed for solutions of computational linguistics and NLP problems of Sindhi language. This study verifies the annotation accuracy of Sindhi NLP tool and assesses the performance of machine learning supervised classification model. Supervised model [3] validates the Sindhi text and evaluates it through test dataset. The purpose of this research study is to identify and analyse the Sindhi text sentiment structurization and sentimentally analysed data. Structurization has been done on the basis of five Ws. The questions which are asked in form of five Ws, clear the context of text. No proper research work has been found on Sindhi text structurization for sentiment analysis, therefore, this work generates new path for research on Sindhi corpus for sentiment analysis, semantic analysis, corpus analysis [4] and other linguistics features analysis.

Nowadays, sentiment analysis technique is growing as large number of organizations focus on reviews, sentiments and opinions of people for polarity analysis [5]. Sentiment analysis method is one of the significant methods of NLP [6]. Sindhi text is morphological rich and grammatically complex [7] and users of Sindhi language are settled all over the world [8] thus to work on Sindhi text corpus for sentiment analysis and structurization enable Sindhi users to express their reviews and opinions as well as provide organizations with information to evaluate the sentiments and opinions. Sentiment structurization [9] clarify the status and history of sentiments and helps in tracking the sentiments summaries.

II. SINDHI TEXT STRUCTURIZATION FOR SENTIMENT ANALYSIS

Sentiment analysis performs vital role in assessing the emotions and feeling of people as well as providing summaries of polarity results to organizations and other concerns. Reviews on products and personalities are very much important for organizations and personalities thus, text structurization divides the sentence properly to know the status of sentiments, actor or reviewer, reason of modification, place and time of modification. Structurization of text is done on the basis of five questions using five Ws. Text structurization of Sindhi text **شازيه فيس بک تي لکيو ته سامسنگ سني موبائيل فون آهي** (Shazia wrote on facebook that Samsung is good mobile phone) for sentiment summarization and analysis is done using five Ws questions properly.

Who: It shows that who expressed the opinion. For example **شازيه فيس بک تي لکيو /Who** (Shazia wrote on Facebook. /**Who**)

What: It shows the opinion of actor. For example Sindhi sentence **شازيه چيو ته سامسنگ سني موبائيل فون آهي** (Shazia said that Samsung is good mobile phone) is structured as:

شازيه چيو ته **/Who**

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سامسنگ سٺي موبائيل فون آهي /**What**

(Shazia said /Who Samsung is good phone /**What**.)

Where: It shows the place from where opinion is expressed or opinion is modified. For example Sindhi sentence **شازيه فيس بڪ تي لکيو ته سامسنگ سٺي موبائيل فون آهي** (Shazia Wrote on Facebook that Samsung is good mobile phone) is structured as:

شازيه /**Who**

فيس بڪ تي لکيو ته /**Where**

سامسنگ سٺي موبائيل فون آهي /**What**

(Shazia Wrote **/Who** on Facebook **/Where** that Samsung is good mobile phone **/What**.)

Why: It shows reason of modification of opinion. For example Sindhi sentence **شازيه فيس بڪ تي لکيو ته سامسنگ سٺي موبائيل فون آهي** is modified to compare Samsung mobile phone with others. The sentence is modified and structured as under:

شازيه پنهنجي راءِ کي/**Who**

فيس بڪ تي/**Where**

5 وڳين بدلائيندي لکيو ته /**When**

سامسنگ ٻين موبائيل فونز کان بهتر موبائيل فون آهي /**What**

(Shazia modified her opinion /**Who** in comment on Facebook /**Where** at 5 PM /**When** that Samsung is better Mobile phone than other mobile phones. /**What**.) The reason of modification in opinion is to compare Samsung mobile phone better than other mobile phones as it may be found better by opinionated person.

When: It shows the time of modification of opinion. When opinion is modified in above sentence than time is noticed. For example Shazia modified her opinion on Facebook regarding mobile phone at 5 PM.

Thus, sentiment structurization is signification process for keeping opinion polarity records of users, which help the organizations, decision makers or concerned persons in knowing the current and previous opinions of users.

III. Material and Methods

Problem of this research study is to evaluate the Sindhi text corpus for analysis of sentiment summerization and analysis. Sentiments show the view of people on different topics, thus structurization sections the text into separate topics. This study has tried to solve the NLP problems of Sindhi text sentiment analysis through structurization and machine learning supervised model. Model analyzed each part of structurization and sentiment polarity which are identified from Sindhi text corpus. Results show the performance of Sindhi NLP tool (http://www.sindhinlp.com/) for sentiment analysis and supervised classification model. Sindhi sentiment analysis has been done using Sindhi lexicons, which are identified through four part of speech like Noun, Adjective, Adverb and Verb.

Sindhi corpus is tagged with universal POS (UPOS) tag set to identify the senti-words. For exapmple Sindhi sentence **منهنجي ڪار سٺي آهي** (my car is good). Sindhi NLP tool tags this sentence like .AUX / ***آهي*** ADJ / ***سٺي*** NOUN / ***ڪار*** PRON / ***منهنجي*** In this sentence noun car is qualified by adjective good, which increase the confidence level of positive polarity. Sentiment analysis tool analyze the Sindhi text and finds out the senti-words. The senti-words are weighted with numbers. The weights are calculated to find out the average of each polarity. Finally, confidence level is measured on basis of high average rate of polarities which are positive and negative. High confidence level of polarity is described as the result of sentiment analysis.

Majority of sentiments are derived through Adjectives because adjectives qualify or disqualify the noun. The subjectivity of sentiment is found through adjectives as adjectives are very much important for sentiment analysis [10] (**Taboada** et al. 2011). For example Sindhi sentence **انب مٺو آهي** (Mango is sweet) presents the positive polarity. Polarity is assessed on basis of Sindh lexicon مٺو (Sweet) which is adjective whereas, Sindhi word **انب** (Mango) is noun. Sindhi word **سٺو** qualifies the Sindhi noun word **انب** Sindhi sentiment analysis tool has analyzed this sentence on basis of mapping UPOS tag set . The lexicon **مٺو** (Sweet) is tagged with UPOS ADJ which expresses positive sentiment thus the confidence level of positive polarity is high. Fig. 1 shows the sentiment analysis results of Sindhi **انب مٺو آهي** (Mango is sweet). Fig. 1 shows the number of lexicons which are used in the sentence, positive and negative weights as well as confidence level which shows average weight of both poalrities. As there is no negative polarity found in the sentence, thus confidence level is observed on basis of positive polarity only.

Fig. 1. Sentiment analysis of Sindhi sentence showing positive polarity.

At the same time, another Sindhi sentence **هي انب کٽو آهي** (This Mango is sour) describes negative polarity of sentence. Here Sindhi adjective lexicon **کٽو** (sour) shows negative sentiment which leads to negative confidence level of polarity of sentence. Sindhi sentiment analysis tool observes tagging and polarity status of lexicons and performs sentiment analysis accordingly. Fig. 2 shows the sentiment analysis results of Sindhi sentence **هي انب کٽو آهي** (This Mango is sour).

Fig. 2. Sentiment analysis of Sindhi sentence showing negative polarity.

A. Sindhi Corpus Dataset

Sindhi corpus is processed for sentiment structurization and analysis to build dataset for supervised machine learning processing. This dataset is developed for this research study, however, computational linguist may use this dataset for further research on Sindhi text and sentiment structurization analysis. This Dataset is comprised of 9779 records and 11 attributes. Polarity of sentences is identified with four categories which are shown in Table 1 with percentage of usage:

TABLE I. SINDHI CORPUS POLARITY IDENTIFICATION

Polarity	Total Number in %
Positive	60.32
Negative	11.15
Mix	7.55
Neutral	20.96

There is a large number of positive polarity and less number of mix polarity which are identified from Sindhi sentiment analysis dataset. Mix polarity is identified from those sentences which show both positive and negative polarities using discourse marker. Discourse marker separates the parts of Sentence. For example Sindhi sentence **اسان جو شهر سٺو آهي پر ماڻهو ان جو قدر نٿا ڪن** (Our city is good but people do not take care of it) presents two parts. First part **اسان جو شهر سٺو آهي** (Our city is good) which shows positive polarity because adjective lexicon **سٺو** (good) shows positive sentiment and second part **ماڻهو ان جو قدر نٿا ڪن** (people do not take care of it) shows negative polarity because Sindhi adverbial lexicon **نٿا** (not) shows negative sentiment. Sindhi discourse marker **پر** (but) connects both parts of sentence. Thus, polarity of this sentence is Mix. Fig. 3 shows the sentiment analysis results of Sindhi.

Fig. 3. Sentiment analysis of Sindhi sentence showing mixed opinion of text.

All records of corpus are structured with different number of Ws to segment the sentences. Each W takes dissimilar score from Sindhi corpus because all Ws are not used for each record. Table 2 shows total number of each W in percentage form. The **What** is used more than all other Ws because majority of sentences are showing opinions.

TABLE II. SINDHI CORPUS 5 WS STRUCTURIZATION

Ws Structurization	Total Number (in %) of Ws annotated to Sindhi text
Who	55.22
What	97.98
Where	42.07
Why	31.88
When	35.24

Sindhi corpus dataset is analyzed for identification of DTM and TF-IDF matrices using N-gram model, where N=3. The frequency of grams show the significance of Sindhi corpus dataset, thus, frequency is shown in form of document term matrix (DTM) and Term Frequency-Inverse Document Frequency (TF-IDF). DTM is consisted of C columns and D rows, therefore, M= C x D. Here, columns present the distinct language features which are vectors of matrix and rows show the number of documents which show the availability of features in documents. Sindhi language is complex language grammatically and morphologically, therefore, there is good number of adjoined words available in Sindhi corpus. Table 3 shows the distinct vectors and their frequency in Sindhi corpus dataset. DTM is comprised of 9779 rows × 2323 columns. Results of frequencies are total sum of Sindhi language features available in Sindhi corpus dataset. Results show the complexity of Sindhi corpus data set.

TABLE III. DTM OF SINDHI CORPUS DATASET USING TRI-GRAM MODE

Frequency in all documents	Vectors / Features of DTM in tri-gram form
18	يا پيو ڪو
18	يا شعوري ڪوشش
17	هي خود شاگرد
17	هوندا آهن انقريب
18	هوشيار هجي امير
17	هن بدمست وڏيري
17	هائوس قومي ٿيم
31	ڳٺايو قوم فرض
31	ڳٺايو سنڌي ڳٺايو
.....	......
17	آخر مرد عورت
17	آخر غربت بک
31	آخر سنڌ افغانين
17	آجياڻو نوازشريف خطاب
17	آباد ڪرين پٺائي
11	آباد ڪرين اتي
70	آءُ پنهنجو پسند
18	آءُ آڏو پيش

Distinct terms are identified from the documents of Sindhi structured corpus through TF-IDF technique, thus, weight of features of corpus show the significance of terms. Study tracks the Latent Semantic Analysis (LSA) model to generate the TF-IDF matrix and analyze the relations of features with all documents available in Sindhi corpus data set. LSA extracts and conclude the relations between features and related documents automatically and statistically [11]. Stop words are removed from the Sindhi corpus dataset to build TF-IDF matrix. This matrix is two dimensional matrix, first dimension shows columns which show features and second dimension shows rows which present documents. Matrix is developed on basis of N-grams model where N=3. Table 4 shows the results of TF-IDF technique extracted from Sindhi corpus. TF-IDF matrix is comprised of 9779 documents and 4231 Sindhi language features.

Sindhi corpus dataset is significant dataset for supervised machine learning analysis. Sindhi language features are identified through DTM and TF-IDF to know the Sindhi language features and variations.

TABLE IV. TF-IDF OF SINDHI CORPUS DATASET USING TRI-GRAM MODEL

Doc #	Feature Name	TF-IDF	Doc #	Feature Name	TF-IDF
0	1860	0.4526	2	3369	0.2450
0	1068	0.5148	2	3004	0.2450
0	326	0.5148	2	482	0.2450
0	4175	0.5148	2	539	0.2304
1	4163	0.4009	2	1309	0.2304
1	1168	0.4580	2	3118	0.2450
1	4161	0.4580	2	3597	0.2450
1	1943	0.4580	2	2864	0.2450
1	4162	0.4580	2	3260	0.2304
...	...	...	...	...	...
9773	143	0.2	9776	498	0.5329
9774	289	0.4082	9776	522	0.5983
9774	1933	0.4082	9776	1891	0.5983
9774	4062	0.4082	9777	507	0.3779
9775	3747	0.3731	9777	1491	0.3779
9775	264	0.4149	9778	290	0.7071
9775	2212	0.41491	9778	3048	0.7071

IV. RESULT ANALYSIS

Supervised classification of Sindhi sentiment analysis corpus data set is done using dissimilar machine learning method to evaluate and assess the multi- classes. This study shows the comparative performance of supervised methods on Sindhi sentiment analysis corpus dara set. The performance of supervised classification methods is observed on basis of precision, recall and f-measure rates. F-measure combines the precision and recall; therefore, it is harmonic mean of precision and recall

$$\text{Precision} = \frac{\text{true positive}}{\text{true positive} + \text{false positive}} \qquad (1)$$

$$\text{Recall} = \frac{\text{true positive}}{\text{true positive} + \text{false negative}} \qquad (2)$$

The cross validation technique is used to validate and evaluate proper results. It works randomly using 10 folds to validate the training set which is 80% of data set and evaluate the test set which is 20% of data set. Structurization is analyzed using two machine learning methods. Structurization of Sindhi corpus is analyzed to know the precision, recall and f-measure scores of relevant records. Table 5 shows supervised machine learning analysis which is done on five Ws structurization. This analysis is performed using SVM Non-linear as dataset is labelled with multi-classes. Precision shows good number of positive predictive values of all Ws, whereas, sensitivity of all relevant records shows good recall results. Thus SVMS work better. Multiple hyper- planes divide all classes properly and give better results. Sindhi is complex language as it uses all forms of morphology as well as major number of bi-grams and tri-grams in its text. Therefore, results of SVM non-linear are better in this condition.

TABLE V. MACHINE LEARNING ANALYSIS OF 5 WS STRUCTURIZATION OF SINDHI DATASET USING SVMS CLASSIFIER

Ws Structurization	Precision AVG	Recall AVG	F-score AVG
Who	63	75	69
What	99	100	99
Where	61	62	60
Why	66	69	64
When	65	67	63

Another machine learning method K-NN is applied on Sindhi corpus dataset structurization to know the statistical results in shape of precision, recall and f-measure rates. K-NN is tested to know the proper value of K. Fig. 4 shows the better value of K for testing of accuracy of K-NN. In this study value of k is set to 2.

K-NN has analyzed all nearest neighbors according to value of K to evaluate and analyze the five Ws structurization. Results of precision, recall and f-measure are shown in Table 6. Precision shows better positive predicted values which are evaluated from retrieved records whereas, recall results show sensitivity of five Ws structurization which are recovered from all relevant records. F-score shows better accuracy of test data which is derived from Sindhi sentiment structurization corpus dataset. Thus, f-score validates the performance of binary classification which is done on Sindhi dataset.

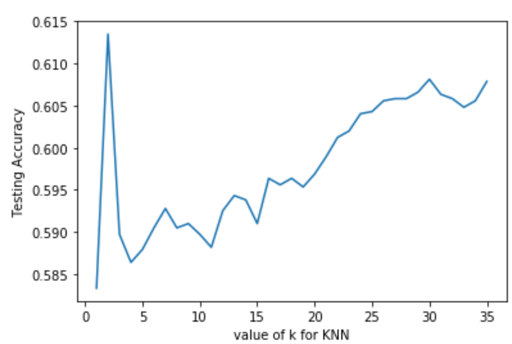

Fig. 4. Value of K for testing accuracy.

TABLE VI. MACHINE LEARNING ANALYSIS OF 5 WS STRUCTURIZATION OF SINDHI DATASET USING K-NN CLASSIFIER

Ws Structurization	Precision AVG	Recall AVG	F-score AVG
Who	65	62	63
What	99	100	99
Where	64	64	64
Why	67	69	68
When	65	66	65

Class polarity is labelled to know the accuracy rate of labelling of each target variable. This class is comprised of four polarity variables which are labelled to records according to their polarity. Both classifiers show different measurement rates. SVM non-linear classifier has performed better on Sindhi corpus dataset using cross validation with 10 folds. 80% of dataset is used as training dataset whereas remaining portion is used as test dataset. Measurement of dataset is observed through precision and recall scores. The relevant records are assessed with true relevant records through precision and relevant records are evaluated from all records through recall. However, results show better performance of supervised model which applied on Sindhi dataset. Table 7 shows measurement scores which are observed through true relevant and false relevant records from Sindhi data set using machine learning classifier SVMs.

TABLE VII. MACHINE LEARNING ANALYSIS OF SENTIMENT ANALYSIS OF SINDHI CORPUS DATASET USING SVMS

Polarity	Precision AVG	Recall AVG	F-score AVG
Positive	66	98	79
Negative	66	60	61
Mix	75	75	75
Neutral	89	22	35

Class polarity is also measured through K-NN classifier to differentiate the performance of both classifiers. Value of K is set to 2 to find out the nearest neighbors. Measurement of class polarity differentiates the assessment of true relevant and false relevant polarity categories. Table 8 shows the precision, recall and f-score of class polarity.

TABLE VIII. MACHINE LEARNING ANALYSIS OF SENTIMENT ANALYSIS OF SINDHI CORPUS DATASET USING K-NN

Polarity	Precision AVG	Recall AVG	F-score AVG
Positive	68	89	77
Negative	61	64	62
Mix	58	54	55
Neutral	42	21	28

V. CONCLUSION

This study has tried to solve the NLP problems of Sindhi language as this language is one of the significant languages of Asia. There is no proper work done on sentiment analysis for Sindhi text thus, this is first work which is done on Sindhi language sentiment structurization and analysis. Sentiment structurization has solved the sentiment analysis problems of language for opinion tracking and sentiment summarization. Machine learning supervised analysis of own developed Sindhi sentiment structurization corpus dataset has proved the better performance of model. Precision, Recall, F-score and accuracy of supervised model has given good results on Sindhi corpus dataset. There is more need to work on Sindhi sentiment analysis for visual tracking that organizations can get proper opinions and reviews on their products.

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QRishing: A User Perspective

Ari Kusyanti
Department of Information Technology
Universitas Brawijaya
Malang, Indonesia

Ali Arifin
Department of Information System
Universitas Brawijaya
Malang, Indonesia

***Abstract*—QR Code offers more benefits and features than its predecessor, Barcode, which make it more popular. However, there is no doubt that behind the features and conveniences offered by QR Code, it turns that the QR Code can be utilized to perform QRishing. This study proposes a model based on Technology Acceptance Model (TAM) combined with Perceived Security, Trust, Perceived Behavioral Control, Self-Efficacy and Perceived Risk based on previous research. Data obtained from 300 respondents are then analyzed with Structural Equation Modeling (SEM). The results show that Attitude, Perceive Security and Perceived Risk affect the individual to scan QR Code.**

Keywords—QR code; perceived risk; perceived privacy; trust; Structural Equation Modeling (SEM)

I. Introduction

QR Code is getting more attention in some countries based on the results on the investigation of ScanLife [1] in 2015, which showed that the United States, Spain, France, Brazil and Mexico are five most active countries that scan the QR Code to access product information, entertainment video, mobile applications, etc. Google Trends [2] also conducted a survey of QR Code trend in November 2015-October 2016, with Hong Kong, Taiwan, Singapore, Germany and Austria as the five most active countries scanning the QR Code.

In Indonesia, the use of QR Code is started by Indonesian Ministry of Public Transportation in order to improve public services in traffic and online sea transportation by the Sistem Manajemen Lalu Lintas Angkutan Laut (SIMLALA) application [3]. In addition, Indonesian General Department of Taxation also uses QR Code for their e-invoice payment system [4]. In addition, Lembaga Pangan Pengkajian Obat-obatan dan kosmetika Majelis Ulama Indonesia (LPPOM-MUI) has built QR Code Scanner-based applications to enable customers to check the halal certification of a product through the device such as mobile phones [5]. Some of the above examples indicate that the use of QR Code in Indonesia has been getting more popularity.

Research conducted by [6] examines how users interact with QR Code that is placed in an urban space called PlaceTagz. PlaceTagz is located in various locations located in Melbourne such as cafeterias, libraries and public toilets. When someone scans PlaceTag, the person is taken to a dialog box where he can read comments from previous visitors and also that person can leave his own comments. The results of this study indicate that curiosity is the primary motive of users to scan non-contextual QR codes. With curiosity being the primary motivation of the user to interact with unknown sources, the user tends to ignore security threats related to the source of the QR Code whether verified correctly or not. It has been found several cases related to QR Code, such as that one of Heinz customer (Heinz known as a food processing company in Germany) reported that the QR Code has been scanned in order to follow the Heinz company promotion to order a bottle of tomato sauce but in fact it is instructed her to direct to a porn company site called FunDorado [7]. Other case had occurred in Russia, that the perpetrator of a crime use QR Code technology to attract users so that they download Android apps that contain malware. Applications downloaded by the target named Jim then will send a text message to victims who can steal up to 5 USD victim’s air time [8].

Given the considerable risks posed by the QR Code, it is worth a study to further examining this issue. Kieseberget et al. [9] has been conducting research with respect to the QR Code and how QR Code can be used to attack the target by manipulating the QR Code to make the target interested to scan it. After scanning, the target will get caught in the phishing attack that had been planned by the attackers, known as QRishing. This is due to most of users are less paying attention to security and trusting the QRCode which they scan. In addition, research that examines aspects of human and computer interactions especially in the field of QR Code security has been done by [6] and [10].

In a study conducted by [10] found that QR code-initiated phishing attacks by conducting two experiments in the city of Pittsburgh, surveillance and a QRishing experiment. Within their surveillance experiment, they observe how users interact with QR Code and whether the user is scanning QR Code or not. Furthermore they also observe the proportion of users who scan the code but refuse to visit the encoded URL by visually monitoring the interaction of the user. To perform the experiment, they put up QR Code posters and cameras used to record the interaction of the user. In this experiment, they divided the QR Code on three types of posters and leaflets to find out assess the susceptibility of such a phishing attack. In their deployed QR codes, a link to a survey was encoded. The experiment contains a series of questions used to identify factors and behaviors of people who scan QR Code. Similar to research conducted by [10], research [6] found that curiosity is the main motivation for smartphone users to scan the code. Their findings highlight the need for further research on adequate tools to support the user in detecting potential threats as they are mostly scanning unverified codes because of their curiosity. Their results also found that most of the users who scan the QR Code do not provide the proper tools to be able to automatically detect attacks and minimize the impact of user's privacy and security.

However apart from its sophistication and ease of use, QR Code also causing damage. However, this study did not model the behavior of QR Code users that may explain why they want to scan a QR Code. Specifically, our study proposes a similar study on the QR Code by modeling the QR Code user behavior which is a modified research models of Cheng et al. [11]; Shin [12]; Ajjan and Hartshorne [13]; and Martins et al. [14].

The outline of this research is in Section 1 explains the background of the issues raised, while Section 2 describes the literature review which contains an explanation of the QR Code and the variables used in this study. Section 3 explained research model to be used along with the formulation of the hypothesis. Afterwards, Section 4 describes the data analysis and presented in the form of data, and in Section 5 is the discussion exposure from the results of data analysis that has been done. Finally Section 6 is the exposure of the conclusions from the results of data analysis that has been obtained.

II. Literature Review

A. QR Code

Quick Response (QR) Code is a matrix of two-dimensional black and white pixels that can be used to store or encode data or information, which information or data can be obtained simply by scanning the QR Code [15]. The information encoded in the vertical and horizontal directions, thus the data can be stored several hundred times more than the Barcode. QR Code can be read by a QR reader application. Data can be accessed only by capturing the QR Code images using the smart phone's camera, then the QR reader application will process the image to be interpreted and displayed to the smart phone screen [9]. QR Code is more popular because of higher information density and increasing the reading compared with Barcode [15].

For our study, we perform a modification of QRishing, we placed posters in our university and nearby as in Fig. 1 from 23 November - 30 of December 2016. The poster is actually a fake promotional poster which offers respondents with a free USB Stick as a reward if they scan the QRCode. This poster contains the URL address (http://tinyurl.com/KuisionerQRCode) which is a page for fill in the online questionnaire. The poster is actually a fake promotional poster which offers respondents with a free USB Stick as a reward if they scan the QRCode.

B. Technology Acceptance Model with the Addition of Perceived Web Security Construct

TAM is a comprehensive research model used to predict the acceptance factor for someone to use the services of a particular technology or information systems. Research conducted by [11] discussed factors affecting clients to use the Internet Banking (IB). The theoretical model in this study based on the Technology Acceptance Model (TAM) with the addition of perceived web security construct to predict customer behavior intention to adopt IB. Retrieving data using questionnaires to 203 customers in Hong Kong were selected randomly. Then the data were analyzed using the Structured Equation Modeling (SEM) to evaluate the strength of the relationship between the hypothetical construction which includes Perceived Ease of Use and Perceived Web Security, Perceived Usefulness, Attitude and Intention to Use. The results showed that Attitude, Perceived Web Security and Perceived Usefulness effect on person's intention to use IB.

Fig. 1. Poster containing QR code.

C. Trust, Security and Privacy

Research conducted by [12] discussed the effect of trust, security, and privacy of the individual to use social networking sites. Retrieving data from questionnaires of 370 students of Sungkyunkwan University in South Korea, the data were analyzed using the Structured Equation Modeling (SEM) to evaluate the strength of the relationship between the hypothetical construction which includes Perceived Security, Perceived Privacy, Trust, Attitude and Intention. The findings indicate that the Trust affect Attitude, then Security affects the Trust which was adopted in this study.

D. Decomposed Theory of Planned Behavior (DTPB)

Research conducted by [13] discussed the factors that influence the decision of the Faculty at the University of North Carolina United States to adopt Web technologies 2.0 in the methods of learning in the classroom. As for the research model used is decomposed Theory of Planned Behavior (DTPB). The results showed that the Subjective Norm does not affect Behavior Intention, then only Self Efficacy affecting Perceived Behavioral Intention which was adopted in this study.

E. Unified Theory of Acceptance and Use of Technology (UTAUT) and Perceived Risk

Research conducted by [14] discussed with respect to understanding the determinants of major adoption of Internet Banking (IB) for banks and customers. The results of the study support some of UTAUT relationship, such as Performance Expectancy, Effort Expectancy, Social Influence and also the role of risk (Perceived Risk) strongly influence Intention which was adopted in this study.

III. Model Structure and Hypothesis

This study uses model from [11] with TAM and Perceived Web Security constructs that has been modified to determine the factors that affect a person using QR Code. The model is also combined with the Trust construct from [12], Subjective Norm construct and Perceived Behavioral Control construct from [4], and Perceived Risk construct from [14].

A. *Constructs Definition*

In this study, there were 13 constructs variable included four constructs of variables which is a second order (performance risk, time risk, social risk, overall risk), and 40 indicators variable. The definition of each construct can be seen in Table 1.

TABLE I. Constructs Definition

Construct	Definition	Ref
Perceived Usefulness (PU)	The extent to which a person believes that using a particular system would enhance his job performance	[11]
Perceived Ease of Use (PEOU)	The extent to which a person believes that using a particular system would be free from excessive effort	[11]
Perceived Security (PS)	The extent to which a person believes that the using a particular system is safe	[11]
Attitude (ATT)	Referring to the positive or negative feelings that affect individual people perform certain behaviors	[11]
Intention to Scan (ITS)	Referring to the person's intent to use (scan QR Code)	[11]
Trust (T)	The trust in the other party that they will behave according to expectations	[12]
Perceived Behavioral Control (PBC)	Individual perceptions about how easy or difficult it is to behave as the effect of perceived behavioral control	[13]
Self-Efficacy (SE)	Self-efficacy is defined as the ability of individuals perceived to behave in certain ways	[13]
Perceived Risk (PCR)		
Performance Risk (PFR)	Possible outcomes are not suitable as desired, and therefore failed to provide the desired benefits	[14]
Time Risk (TR)	Time risk occurs when users lose time due to adopt a particular technology or service	[14]
Social Risk (SR)	Social risk reflects the potential loss of status in social groups, as a result of adopting a particular technology or service	[14]
Overall Risk (ORI)	Overall risk as a result of a combination of risks	[14]

B. *Hypothesis for the Construct*

Adapted from [11], their study using the Technology Acceptance Model (TAM) from [11], with some additional constructs, there are behavioral intention to use, attitude, perceived ease of use and perceived usefulness, then combined with the perceived web security based on research from [11], to determine the factors that affect a person using the IB service. Their study said that the findings are consistent with the findings of [11], where the perceived usefulness (PU) has a strong influence on customer intention to use IB services. Perceived ease of use (PEOU) has influence on perceived usefulness (PU), or it can be said that PEOU have an indirect impact on the intention. According to Davis et al. (1989) cited in [11], PEOU has influence on intention. Referring to [11] that the feeling of safety (perceived web security) is the main factors that influence a person to conduct transactions online, and this finding is consistent with [11]. The final result of [11] shows all the hypotheses are accepted, which are adopted in this study to analyze the factors that affect a person using QR Code. So, from all these statements, we propose the following hypotheses:

H1a: "Perceived Ease of Use (PEOU)" has a positive effect on "Perceived Usefulness (PU)".

H1b: "Perceived Ease of Use (PEOU)" has a positive effect on "Intention to Scan (ITS)".

H2a: "Perceived Usefulness (PU)" has a positive effect on "Attitude (ATT)".

H2b: "Perceived Usefulness (PU)" has a positive effect on "Intention to Scan (ITS)".

H3: "Attitude (ATT)" has a positive effect on "Intention to Scan (ITS)".

H5b: "Perceived Security (PS)" has a positive effect on "Intention to Scan (ITS)".

Adapted from [12] that perceived security is defined as the degree of how a person's trust in the security of the QR Code [12], found that the perception of security affect a person's trust and intention. This is consistent with the [12] finding that the security determines the level of trust. Then Papadopoulou [12] found that there is a positive influence on the attitude of trust and intentions. So, from all these statements, we propose the following hypotheses:

H5a: "Perceived Security (PS)" has a positive effect on "Trust (T)".

H4a: "Trust (T)" has a positive effect on "Attitude (ATT)".

H4b: "Trust (T)" has a positive effect on "Intention to Scan (ITS)".

Based on [13] defines that perceived behavioral control is an individual's perception of how easy or difficult it is to behave as the effect of perceived behavioral control. In [13] found that attitudes and perceived behavioral control have a strong positive influence on the behavioral intention, but subjective norm have no influence on behavioral intention, this is consistent with [13]. So, from all these statements, we propose the following hypotheses:

H6: "Perceived Behavioral Control (PBC)" has a positive effect on "Intention to Scan (ITS)".

H7: "Self Efficacy (SE)" has a positive effect on "Perceived Behavioral Control (PBC)".

Adapted from [14] defines that performance risk, financial risk, time risk, psychological risk, social risk, privacy risk and overall risk is an indicator of second order of perceived risk affecting intention. This is consistent with the finding of [14] that the perceived risk is an important factor that affects a person's intention in using IB which was adopted and adapted by the authors to analyze the factors that affect a person using QR Code. So, from all these statements, we propose the following hypotheses:

H8: "Perceived Risk (PCR)" has a positive effect on "Intention to Scan (ITS)".

Based on hypotheses that have been formulated above, the research model can be seen in Fig. 2.

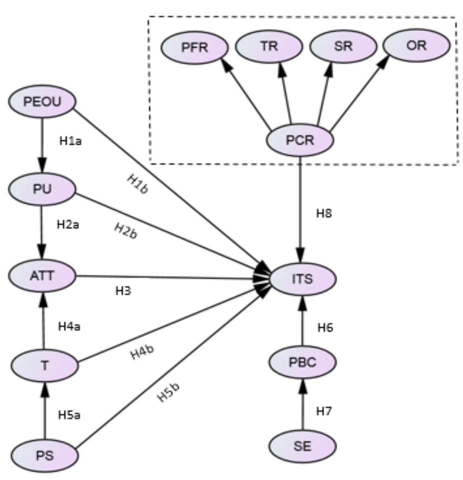

Fig. 2. Reasearch model.

IV. Data Analysis

Respondents in this study is not limited by certain criteria, including the age or gender, everyone can participate as a respondent after scanning the QR Code found on the posters have been distributed by the author, then the respondent will be redirected to the page of filling the questionnaire online which in this study using a Google Form. 300 respondents were obtained for analysis in this study. The sample data were analyzed using SEM (Structural Equation Modeling). The ideal sample size data on SEM method preferably ranges from 200 to 400 data for the model studies with 10-15 observed variables. The author took the middle value of 300 data because if the sample data are below 100 or above 300, it can provide unfavorable analytical results [16].

From the result of filling the online questionnaire by respondents, there are no questionnaires were incomplete and all have passed the test of missing data. For the characteristics of the respondent can be seen in Table 2.

TABLE II. Respondents Characteristic

Age	Total	%	Gender	Total	%
<20	64	21,33	Male	40	62,5
			Female	24	37,5
20-29	236	78,67	Male	119	50,42
			Female	117	49,58

A. Outlier Test

Outlier test is performed by calculating Mahalanobis distance value. In this study the Mahalanobis distance value is 63.69073975. There are 40 data that has value above Mahalanobis distance so that this data can be called outliers and should be eliminated.

B. Missing Data and Outlier

Based on Little's MCAR, there is no missing data in this study. Mahalanobis distance is used to determine outlier data. Data which has Mahalanobis distance of more than 34,805 is considered the outlier and need to be withdrawn. From 300 questionnaires collected, there are 12 outlier data, so the eligible data to be analyzed are 288 data.

C. Reliability and Validity Test

Reliability can be defined as trust, reliability or consistency [17]. A measuring instrument can be said to be reliable if it is have a high level of consistency (high reliability). Reliability test can be measured using Cronbach's alpha values [18], grouping reliability criteria based on the value of Cronbach's alpha, which is excellent if ($\alpha \geqslant 0{,}9$), good ($\alpha \geqslant 0{,}8$), acceptable ($\alpha \geqslant 0{,}7$), questionable ($\alpha \geqslant 0{,}6$), poor ($\alpha \geqslant 0{,}5$) and unacceptable ($\alpha < 0.5$). Referring to Table 3, the authors using Cronbach's alpha values above 0.7 to determine the level of consistency of respondents, in other words, the data can be said to be reliable if it has a value of Cronbach's alpha of more than 0.7.

To test the validity can be tested by average variance extracted (AVE) for each construct [19]. AVE value can be seen in Table 4 for each variable construct in this study. An indicator is said to be valid and worthy to be tested further if the AVE value is greater than 0.5 [19].

From Table 4 it is shown that the AVE value of each construct is more than of 0.5 [19], so it can be said good because of all the variables of indicators has met the AVE criteria.

TABLE III. CRONBACH ALPHA VALUE

Construct	Cronbach's alpha	Explanation
Perceived Usefulness (PU)	0,922	Excellent
Perceived Ease of Use (PEOU)	0,899	Good
Trust (T)	0,890	Good
Perceived Security (PS)	0,944	Excellent
Attitude (ATT)	0,902	Excellent
Intention to Scan (ITS)	0,937	Excellent
Performance Risk (PFR)	0,871	Good
Time Risk (TR)	0,922	Excellent
Social Risk (SR)	0,937	Excellent
Overall Risk (ORI)	0,919	Excellent
Perceived Behavioral Control (PBC)	0,789	Acceptable
Self-Efficacy (SE)	0,901	Excellent

TABLE IV. CONVERGENT VALIDITY EXTRACTED (AVE)

Construct	AVE
PEOU	2.341
PU	2.5351
ATT	2.8826
T	2.3841
ITS	1.5338
PS	1.829
SE	1.6926
PBC	1.6846
PFR	1.9139
TR	1.2694
SR	1.2694
ORI	2.1758

D. KMO and Bartlett's Test

Kaiser-Meyer-Olkin (KMO) and Bartlett's test was used to determine whether the sample data used in the study is sufficient to analyze certain factors. According to [20], it breaks down in detail the criteria of KMO and Bartlett's test that can be seen in Table 5. From the calculation results KMO is 0.908, so it can be said to have a very good criteria (superb). Then for the value of Bartlett's test can be seen to have a value of 0,000 so it can be said to be very significant.

TABLE V. KMO AND BARTLETT'S TEST

Index	Value	Criteria	Ref
Kaiser-Meyer-Olkin	0,908	<0,5 unacceptable	[20]
		0,5-0,7 mediocre	
		0,7-0,8 good	
		0,8-0,9 great	
		>0,9 superb	
Bartlett's test	0,000	<0,001 highly significant	

E. Levene Test

Levene test is used to determine whether the research data obtained was homogeneous or not. Data are considered homogeneous if the value (Sig.> 0.05), but if the value (Sig. <0.05), then the data is considered not homogeneous [21]. The test results showed that all existing indicator variable has a value of Sig. > 0.05, so the data is said to be good because it has met the criteria of homegenity.

F. Normality Test

Normality test is used to determine the normal distribution of the cumulative sample. Normality test can be calculated with the Kolmogorov-smirnov. Samples can be said to be normally distributed because the Sig. 0.2 (meet the criteria Sig.> 0.05) [22].

G. Model Fit

SEM is performed with two steps, Confirmatory Factor Analysis (CFA) to analyze measurement model and Path Analysis to analyze structural model. CFA test results judged on the criteria of goodness of fit (GOF) for overall fit testing. Overall fit model used for testing the suitability of the model with the research data used. For criteria Goodness of Fit (GOF) can be seen in Table 6.

H. Model Fit Test Result

The result of the measurement of goodness of fit is presented in Table 7. Based on these results it can be said that the model used fits the data of respondents. Then for the measurement estimation results of relationship each variable constructs and indicators can be seen in Table 7, which is the result of structural test model fit through path analysis. Relations between constructs and indicators according to [23] can be seen by looking at the p-value and critical ratio (t-value). Referring to the results of the constructs estimation relationship with its indicator refers to Table 8, can be said that there is a significant relationship between the constructs and indicators. So, constructs variable really suitable for measuring variables existing indicators.

TABLE VI. GOODNESS OF FIT INDICES (GOFI) VALUES

Model fit	Item	Criteria	Ref
Measurement model fit	Chi-square (χ^2)	X^2, df, p≥0,05	[24]
	Goodness of Fit Index (GFI)	>0,80	[25]
	Root Mean Square Error of Approximation (RMSEA)	<0,07	[24]
	Root Mean Square Residual (RMR)	≤0,08	[24]
	Normed-fit index (NFI)	≥0,80	[24]
	Comparative fit index (CFI)	≥0,80	[24]
Structural model fit	Factor loading	>0,5 acceptance >0,7 good	[23]
	Critical ratio (t-value)	>1,96	[23]
	P value	* p<0,05 ** p<0,01 *** p<0,001	[26]

TABLE VII. MODEL FIT TEST RESULT

Index	Criteria	Value	Explanation
Chi-Square	X^2, df, p>0,05	1164,07	Fit
GFI	>0,80	0,82	Fit
RMSEA	<0,07	0,05	Fit
RMR	≤0,08	0,05	Fit
NFI	≥0,80	0,88	Fit
CFI	>0,90	0,94	Fit

I. *Hyphothesis Testing*

Referring to Table 8 that the proposed hypothesis can be said to be accepted if the Critical ratio (t-value) > 1.96 and p-value ⩽ 0.05. Table 8 presents the results of hypothesis testing, it appears that there are 8 hypothesis is accepted and the two hypothesis are rejected.

V. RESEARCH RESULT

A. *Discussion on Hypothesis 1*

Based on the hypothesis testing results in Table 8, there are 8 hypotheses that are accepted and the 4 hypothesis are rejected in this study are as follows:

1) H1a: "Perceived Ease of Use (PEOU)" has a positive effect on "Perceived Usefulness (PU)".

H1a is accepted, which means that perceived ease of use of QR Code is influence the perception that it is true by scanning the QR Code can help respondents to accomplish their activity/job. In this case the initial perceptions of respondents think that by scanning a QR Code can improve performance on their activity/job. These results are consistent with [11] and [26] cited in [11].

TABLE VIII. HYPOTHESIS RESULT TESTING

Relationship	Critical ratio (t-value)	p-value	Explanation
PU <--- PEOU	13.647	***	Accepted
ITS <--- PEOU	-.567	.571	Rejected
ATT <--- PU	9.722	***	Accepted
ITS <--- PU	0.659	0.51	Rejected
ITS <--- ATT	8.77	***	Accepted
T <--- PS	10.504	***	Accepted
ITS <--- PS	3.613	***	Accepted
ATT <--- T	6.424	***	Accepted
ITS <--- T	-.463	.643	Rejected
ITS <--- PBC	-1.019	0.308	Rejected
PBC <--- SE	11.563	***	Accepted
ITS <--- PCR	3.981	***	Accepted

2) H1b: "Perceived Ease of Use (PEOU)" has a positive effect on "Intention to Scan (ITS)".

H1b is rejected, which means that the ease of use of QR Code have no direct effect on respondents' intention to scan the QR Code. PEOU is going to affect the intention only if the existence of perceived usefulness (PU) or if it is useful. So it can be said that PEOU have an indirect impact on intention. These results are consistent with [11].

3) H2a: "Perceived Usefulness (PU)" has a positive effect on "Attitude (ATT)".

H2a is accepted, which means that respondents find it is worthwhile to scan the QR Code because basically they already have positive feelings toward the QR Code that is scanned by them. These results are consistent with [26] and cited in [11].

4) H2b: "Perceived Usefulness (PU)" has a positive effect on "Intention to Scan (ITS)".

H2b is rejected, which means respondents are not going to immediately scan the QR Code even though they know that scanning the QR Code will not be difficult, before they think that the decision to scan is completely positive and profitable. These findings are in contrast to [11].

5) H3: "Attitude (ATT)" has a positive effect on "Intention to Scan (ITS)".

H3 is accepted, which means that respondents' attitudes or perspectives influence them to scan the QR Code. Respondents have positive feelings which will encourage them to scan the QR Code were met. These results are consistent with of [11] and [26] cited in [11].

6) H4a: "Trust (T)" has a positive effect on "Attitude (ATT)".

H4a is accepted, which means that respondents' level of trust will affect their attitude or perspective on QR Code scanned by them. If they trust, it would be encouraged them to think positively that scan the QR Code there is nothing wrong and it is a good idea. These findings are consistent with [12], they found that there is a positive influence of trust on the attitude and intentions. It is also consistent with the [12].

7) H4b: "Trust (T)" has a positive effect on "Intention to Scan (ITS)".

H4b is rejected, which means that a respondents' level of confidence (trust) has no effect directly on individual intention to scan the QR Code. The trust will affect the intention only if the existence of the attitude, so it can be said that the trust has an indirect impact on intention. The result is different from [12] which mention that there is a positive influence between trust on attitude and intention.

8) H5a: "Perceived Security (PS)" has a positive effect on "Trust (T)".

H5a is accepted, which means respondents' will trust the QR Code that is scanned by them when they believe that the QR Code is completely safe and harmless. These findings are consistent with [12], their research found that security perceptions (perceptions of security) affect a person's trust. It is also consistent with the [12].

9) H5b: "Perceived Security (PS)" has a positive effect on "Intention to Scan (ITS)".

H5b is accepted, which means indicates that respondents' perception of security influenced them to use the QR Code which in this case is to scan the QR Code. When they feel safe, they will scan the QR Code without questioning anything. According to [11] states that the feeling of safety (perceived web security) are the main factors that influence persons to conduct transactions online, this finding is also consistent with the findings of [11].

10)H6: "Perceived Behavioral Control (PBC)" has a positive effect on "Intention to Scan (ITS)".

H6 is rejected, which means that the effect of perceived behavioral control does not affect respondents' intention to scan the QR Code. In other words, persons with or without control will still scan the QR Code. The results of this study contrast with [13] who found that attitudes and perceived behavioral control has a strong positive influence on the behavioral intention.

11)H7: "Self Efficacy (SE)" has a positive effect on "Perceived Behavioral Control (PBC)".

H7 is accepted, which means that the respondents find it easy to scan the QR Code, without any special help or capability. These results are consistent with [13] that self-efficacy influences perceived behavioral control. But in this study self-efficacy will affect the intention of respondents to scan the QR Code only if the hypothesis H6 is accepted because self-efficacy has an indirect impact on the intention to scan.

12)H8: "Perceived Risk (PCR)" has a positive effect on "Intention to Scan (ITS)".

H8 is accepted, which means that the perception of risk by respondents would affect their intention to scan the QR Code. When they know and understand the risks that may arise, it can be taken into consideration before they scan the QR Code. This is consistent with the findings [14] that the perceived risk is an important factor that affects a person's intention.

VI. Conclusion and Recommendation

From the discussion, it can be concluded that respondents' intention to scan QR Code technology is directly affected by a respondents' attitude, perceived security and perceived risk. While Perceived Usefulness (PU) and Perceived Behavioral Control (PBC) do not affect respondent's intention to scan the QR Code. In addition, they will not immediately scan the QR Code even though they know that scan the QR Code will not be difficult before they think that the decision to scan is completely positive and profitable. Based on the overall model fit test results shows that the model used in this study is suitable and appropriate to examine the factors that affect person's intention to scan the QR Code. For future study, this research model can be used with different object, demographics and different location and also could be added new relevant constructs, so that it can be used as a comparison with the results of this study.

This study is the first step to appeal and increase user safety awareness in order not to scan QR Code without any proper tool to be able to automatically detect attacks caused by QR Code scan.

Appendix

Perceived Usefulness (PU) According to [11]	
a	Using the QR Code would enable me to accomplish my tasks more quickly
b	Using the QR Code would me it easier for me to carry out my tasks
c	I would find that the QR Code useful
d	Overall, I would find using the QR Code to be advantageous

Perceived Ease of Use (PEOU) According to [11]	
a	Using the QR Code service is easy for me
b	I find my interaction with the QR Code services clear and understandable

c	It is easy for me to become skillful in the use of the QR Code
d	Overall, I find the use of the QR Code services easy

Trust (T) According to [12]	
a	I trust the QR Code that I scanned
b	I trust the information in the QR Code that I scanned
c	I trust the source who has made a QR Code that I scanned
d	I believe that if I scan QR Code, I can meet needs or things that I want

Perceived Security (PS) According to [11]	
a	I would feel secure when I scan QR Code
b	QR Code is secure to be scanned
c	I would feel totally secure to scan QR Code
d	Overall, QR Code is secure to be scanned

Attitude (ATT) According to [11]& [13]	
a	Using the QR Code is a good idea
b	I would feel that using the QR Code is pleasant
c	In my opinion, it would be desirable to use the QR Code
d	The advantage using the QR Code outweighs the advantages of not using it
e	In my opinion, using the QR Code is a wise idea

Intention to Scan (ITS) According to [11]	
a	I would use the QR Code for my activities or to get things that I want
b	Using the QR Code for handling my activities or to get things that I want is something I would do
c	I would see myself using the QR Code for handling my activities or to get things that I want is something I would do
Perceived behavioral control (PBC) According to [13]	
a	I have the knowledge and ability to use the QR Code
b	Using the QR Code technology is entirely within my control

Self-efficacy (SE) According to [13]	
a	I know enough to use the QR Code technology
b	I could easily use the QR Code technology on my own
c	I would feel comfortable using the QR Code

Performance Risk (PFR) According to [14]	
a	QR Code might not perform well and create problems for my activity or things that I want
b	The probability that something's wrong with the performance of QR Code is high
c	Considering the expected level of service performance of QR Code, for me to use QR Code it would be risky

Time Risk (TR) According to [14]	
a	I think that if I use the QR Code the I will lose time due to having to switch to a different way to help my activity or things I want
b	Using QR Code would lead to a loss of convenience for me becase I would have to waste a lot of time for adapting

Social Risk (SR) According to [14]	
a	If I use the QR Code, it would negatively affect the way others think of me
b	Using the QR Code would lead to a social loss for me because my friends and relatives would think less highly of me

Overall Risk (ORI) According to [14]	
a	On the whole, considering all sorts of factors combined, it would be risky if I use QR Code
b	Using the QR Code to help my activity or things that I want would be risky
c	QR Code is dangerous to use
d	I think that using of QR Code would add great uncertainty to my activity or things that I want would

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Impact of External Disturbance and Discontinuous Input on the Redundant Manipulator Robot Behaviour using the Linear Parameter Varying Modelling Approach

Sameh Zribi
Research Laboratory LARA in Automatic Control,
ENIT, University of Tunis El Manar,
Tunis, Tunisia

Jilani Knani
Research Laboratory LARA in Automatic Control,
ENIT, University of Tunis El Manar,
Tunis, Tunisia

Hatem Tlijani
Research Laboratory LARA in Automatic Control,
ENIT, University of Tunis El Manar,
Tunis, Tunisia

Vicenç Puig
Department of Automatic Control (ESAII),
University Polytechnic of Catalonia,
Barcelona, Spain

***Abstract*—This paper is concerned with the synthesis of dynamic model of the redundant manipulator robot based on Linear Parameter Varying approach. To evaluate its behavior and in presence of external disturbance several motions profiles are developed using a new algorithm which produce smooth trajectories in optimal time. The main advantages of this proposed approach are its robustness and its simplicity with respect to the flexibility structure, to the motion profile and mass load variations. Numerical simulations with several tasks show that in presence of mass load variation the desired trajectory is more efficiently followed by the LPV model than the dynamic model of the studied mechanism. Its performances are ensured using the smoothest trajectory designed by the Eighth-degree polynomial profile than the Fifth-degree polynomial one and the trapezoidal one.**

Keywords*—Redundant manipulator robot; flexible structure; linear parameter varying approach; discontinuous torque; external disturbance

I. Introduction

Redundant manipulators robots, the combination of rigid and flexible structures mounted in series are of great interest in a number of applications in the modern industry [1]-[3].

Recently, the use of these manipulators containing flexible arm has received much attention. It has been an important progress several tasks like in planning [4], [5], design [6] and control [7], [8]. It gives more feasibility to robotic mechanisms because of the existence of several solutions in the specified workspace.

However, the dynamic complexity of redundant manipulator robot related to the flexible structure may cause some difficulties especially in high speeds such as external disturbance and highly nonlinearity [8]. In order to cope with this problem, we propose to apply the linear parameter varying approach to the calculated nonlinear model of the redundant manipulator robot in the first step. Then, several motions profiles are applied to evaluate the system's behaviour with a variable mass load as an external disturbance.

The contribution of this paper consists of simulating the Linear Parameter Varying (LPV) model of the considered robotic system using several inputs and evaluating the system's performances in presence of external disturbances and discontinuous inputs.

This paper is organized as follows: In Section II, the trajectory generation overview of several motions profiles is detailed. Section III deals with the presentation of the dynamic modelling of redundant manipulator mechanism followed with its LPV model. In Section IV, the simulation results testing the dynamic performance of our mechanism by applying the motions profiles are analysed with varying of its mass load. Section V presents some concluding remarks.

II. Trajectory Generation Overview

In the scientific literature, almost all techniques on the problem of trajectory planning are focused on the parameter optimization [8]. The algorithms with optimized time were the first proposed techniques of trajectory generation in the literature. Moreover, some applications require the algorithms for optimized energy because of limited capacity for the energy source (for example underwater robots).

The regularity's degree of inputs will directly touch the excitation order of vibrational modes of the robotic mechanism. A trajectory containing a high and discontinuous acceleration causes during movement an important vibrational excitation of some joints of the mechanism or its entire structure [8]. In order to minimize the effector vibration and to suppress its residual vibration, the motion profile must be characterized by a limited jerk [8], [9]. So, using continuous acceleration, a motion profile with a limited jerk will be obtained and a smooth movement will be guaranteed. Unlike excessive jerk, its values can cause the excitation of vibrations in the mechanism structure [8].

The trajectory generation mechanism generates the reference profiles for the control system in order to ensure that the manipulator follows the planned trajectories [10]. It consists of generating a temporal sequence of the values obtained by trapezoidal and polynomial functions as the desired trajectory.

A. Trapezoidal Motion Profile

Using the mathematical principle appointed by the Bang-Bang profile, the researcher Hermes formulated the trapezoidal motion Profile [11]. This profile consists of ensuring the saturation of the acceleration variable of control plant when its level is switched several times between its extreme values. This saturation leads to optimize the time, whereas, it needs the maximum power available to saturate the mechanism actuators [12].

In order to ensure an optimal time, the trapezoidal motion profile leads to generate a continuous speed by ensuring the saturation of both the speed and the acceleration. In the rest of this paper, a time derivation of such function is usually denoted by a number in brackets in the power of this function. The joint position of the trapezoidal profile is defined by

$$\begin{cases} q(t)=\alpha_i t^2+\beta_i & 0\le t\le \tau \\ q(t)=\xi_i(t-\frac{\tau}{2})+\zeta_i & \tau\le t\le T-\tau \\ q(t)=\lambda_i(t-T)^2+\rho_i & T-\tau\le t\le T \end{cases} \qquad (1)$$

and its first derivative is given by

$$\begin{cases} q^{(1)}(t)=2\alpha_i t & 0\le t\le \tau \\ q^{(1)}(t)=\xi_i & \tau\le t\le T-\tau \\ q^{(1)}(t)=2\lambda_i(t-T) & T-\tau\le t\le T \end{cases} \qquad (2)$$

where $q(t)$ is the function according to the time of joint position, τ is the time period of the acceleration phase, T is the time period of movement, $\alpha_i, \beta_i, \xi_i, \zeta_i, \lambda_i$ and ρ_i are constants depending on the initial and the final positions.

Using this profile, its joint velocity is presented along the time period of 0.6 seconds as presented in Fig. 1.

The acceleration saturation produced by this profile is performed by switching between two levels. This switching causes the problem of torque discontinuity that the DC motor cannot track. Moreover, the delivered torque causes a delay in response in the real path compared to the desired path [8]. In order to remedy these problems, others motions profiles called polynomial functions will be proposed.

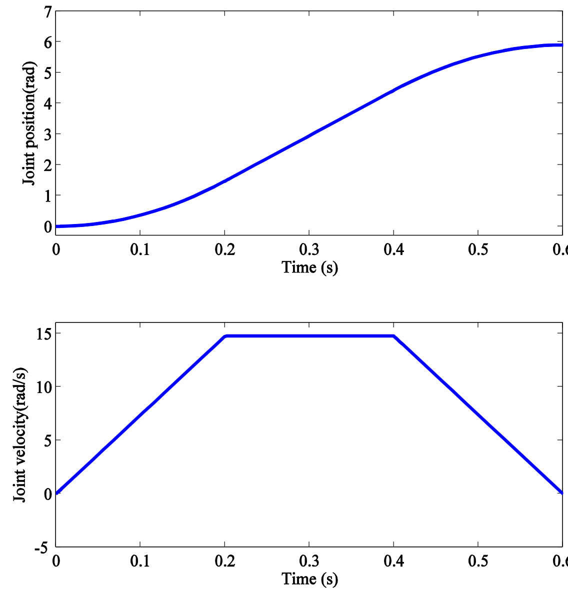

Fig. 1. Joint position and joint velocity for trapezoidal motion profile.

B. Fifth-Degree Polynomial Motion Profile

The three most common approaches are the linear, the fifth-polynomial and the eighth-polynomial interpolations functions. Its general form of these functions is expressed as follows:

$$q(t)=q_0+h(t)D \qquad (3)$$

Where, q_0 presents the initial position, $h(t)$ presents the interpolation function and D presents the difference between the final position q_f and the initial position q_0. In this work, we limited to apply the fifth-polynomial and the eighth-polynomial interpolations functions to the studied mechanism.

Concerning the fifth-polynomial profile, it produces a smooth movement similar to that of the human movement joint. The acceleration provided by this motion profile is characterized by an excitation of natural modes and a minimum jerk, so its movement is appointed by minimum-jerk movement [13].

The joint position of the fifth-polynomial interpolation function is expressed by

$$q(t)=D\left[\frac{6\,t^5}{T^5}-\frac{15\,t^4}{T^4}+\frac{10\,t^3}{T^3}\right]+q_0 \qquad (4)$$

and its first derivative is given by

$$q^{(1)}(t)=D\left[\frac{30\,t^4}{T^5}-\frac{60\,t^3}{T^4}+\frac{30\,t^2}{T^3}\right] \qquad (5)$$

Along the time period of 0.6 seconds, the joints position and velocity of this profile are described in Fig. 2.

In order to improve the fifth-polynomial motion profile by obtaining a smoother movement and by minimizing the response time, the eighth-polynomial function will be explained and then simulated.

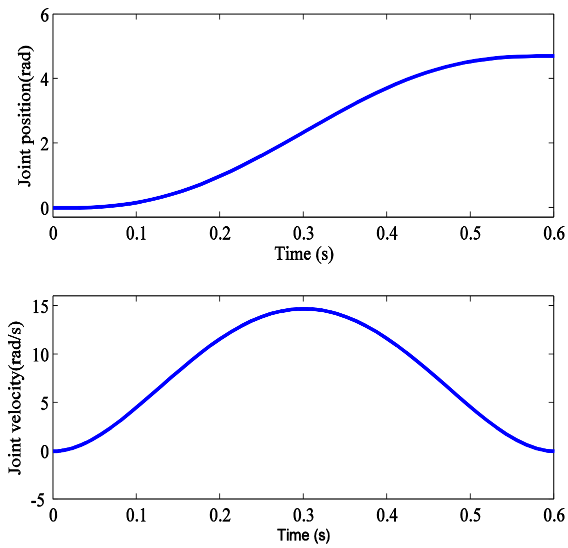

Fig. 2. Joint position and joint velocity for fifth-polynomial profile.

C. Eighth-Degree Polynomial Motion Profile

Smooth trajectories of given path can be generated by eighth-degree polynomial interpolation function [12]. It can be expressed by

$$q(t) = q_f \left(\frac{t}{T}\right)^3 \left[70 - 350\left(\frac{t}{T}\right) + 546\left(\frac{t}{T}\right)^2 - 42\left(\frac{t}{T}\right)^3 + 120\left(\frac{t}{T}\right)^4\right]$$
$$+ I_{nd}\, q_f \left(\frac{t}{T}\right)^3 \left[32 + 160\left(\frac{t}{T}\right) - 288\left(\frac{t}{T}\right)^2 + 224\left(\frac{t}{T}\right)^3 - 64120\left(\frac{t}{T}\right)^4\right] \quad (6)$$

and its first derivative can be defined as follows:

$$q^{(1)}(t) = q_f \left(\frac{t^2}{T^3}\right) \left[210 - 1260\left(\frac{t}{T}\right) + 2730\left(\frac{t}{T}\right)^2 - 2520\left(\frac{t}{T}\right)^3 + 840\left(\frac{t}{T}\right)^4\right]$$
$$+ I_{nd}\, q_f \left(\frac{t^2}{T^3}\right) \left[96 + 640\left(\frac{t}{T}\right) - 1440\left(\frac{t}{T}\right)^2 + 1344\left(\frac{t}{T}\right)^3 - 448\left(\frac{t}{T}\right)^4\right] \quad (7)$$

Where, I_{nd} is a parameter allowing to obtain the smoothest trajectory, it is defined as follows:

$$I_{nd} = V_{max} \left(\frac{T}{q_f}\right) \quad (8)$$

Where, V_{max} is the maximum velocity generated during the trajectory. The eighth polynomial motion profile allows issuing a smooth movement. This smoothness is ensured with this motion profile more than that with fifth-polynomial and trapezoidal motions profiles. Moreover, using the eighth-polynomial motion profile, the robustness of the system is guaranteed opposite to the external disturbances which are presented by the variation of the load mass in our work.

The joints position and velocity of this motion profile are presented along the time period of 0.6 seconds as in Fig. 3.

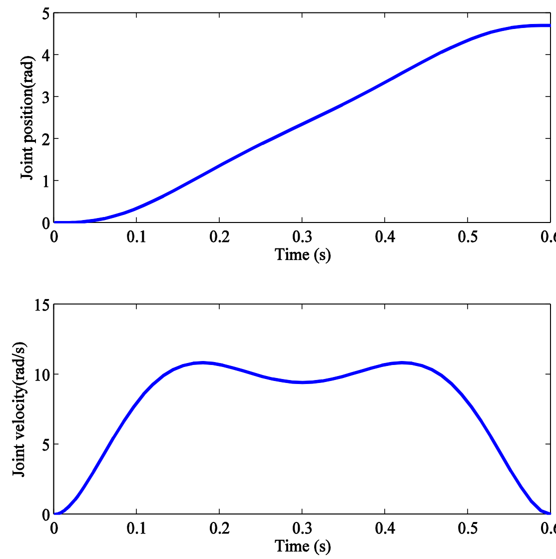

Fig. 3. Joints position and velocity for eighth-polynomial profile.

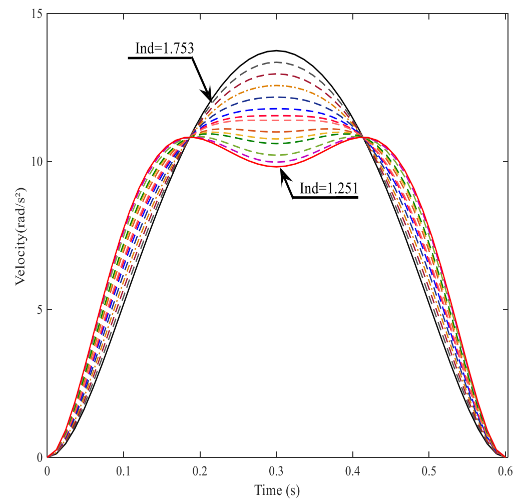

Fig. 4. Velocities profiles of the robot manipulator when I_{nd} is within the interval of natural movements.

In order to generate smooth trajectories using the eighth-polynomial interpolation function, the parameter I_{nd} must be in the interval [1.251, 1.753], as it is presented in Fig. 4 which shows the velocities profiles of the robot manipulator when I_{nd} is within the interval of natural movements.

The use of eighth-polynomial interpolation function with variable parameter (I_{nd}) allows generating a big number of smooth trajectories for a given path. If this parameter is inside this interval, the eighth-polynomial function generates natural movements. We can note that if $I_{nd} = 1.251$, the generated slope of the velocity curve is very sharp at the beginning of the trajectory and its end, so this trajectory has the lowest V_{max} With regard to the case where $I_{nd} = 1.753$, the velocity curve slope is very smooth at the beginning of the trajectory and its end, but this trajectory needs the highest V_{max} [14].

III. Linear Parameter Varying Approach for Dynamic Modelling of Redundant Manipulator Robot

A. Mechanism's Description and Assumptions

Before the dynamic modelling, the redundant manipulator robot is presented by the rigid-flexible manipulator mechanism [15]. It consists of five rigid bodies and the sixth one presenting the end-effector which is considered as a flexible body. A mass load appointed by M is recessed in the free extremity of end-effector. An articulated chain with serial architectures links the robot bodies which are manipulated using six rotary joints. These six rotary joints are ensured by DC motors each one of them is placed directly on each link. This plant is an example of a non-linear, under-actuated and multivariable system. It has as inputs the torques generated by the DC motors and as outputs the values of its articulation angles.

With the aim of simplifying its modelling calculation, only the two last bodies of the system are taken into consideration. The first one C_1 is rigid, whereas the second C_2 is flexible. This flexible solid have a mass load at its end will be treated as a uniform Euler-Bernoulli beam as shown in Fig. 5.

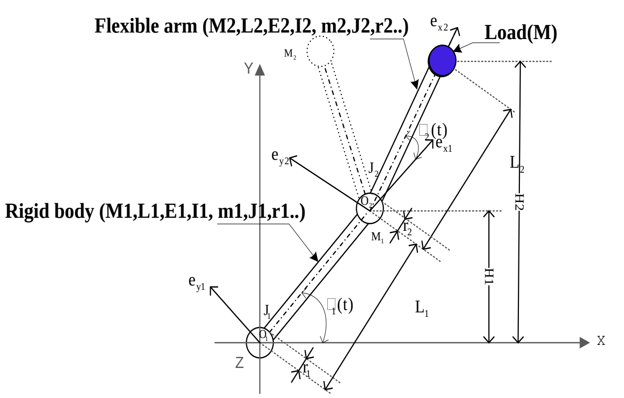

Fig. 5. Two arms of rigid-flexible manipulator robot with its rotary joint.

Where, M_i, L_i, I_i, E_i, m_i and l_i present respectively the mass, the length, the area moment of inertia, the Young's modulus, the mass per length's unit of i^{th} solid, the length of the i^{th} element and r_i, J_i are respectively the radius and the inertia's moment having brought back to the i^{th} articulation. Moreover, $q_i(t)$ presents the rotation angle of the solid i^{th} around the axis Z.

The modelling assumptions will be taking into consideration as follows:

- The robot motion is assumed to be in the vertical plane.
- The shear strain, the effect of the axial force and the rotational inertia of the flexible arm are supposed to be negligible.
- The length of the flexible arm is assumed as constant, in order to avoid the problems appearing from the variability of the flexible arm.
- In order to guarantee the manipulator vibration in the horizontal direction, the depth is considered to be smaller than its length.

B. Dynamic Modelling of the Studied Mechanism

The dynamic modelling of a rigid-flexible manipulator mechanism provides a description of the relationship between the structure motion and the joint actuators torques [16], [17]. The simulation allows analysing the dynamic performances of the manipulator structure, to test the trajectory planning algorithms and to design the control strategies without the need to use the physical system.

In general, the two most common approaches used to establish the dynamic equation of rigid-flexible manipulator mechanism are the Euler-Lagrange formulation and the Newton-Euler method [18].

The Newton-Euler approach consists of correlating the forces coupling acted on the links displacement and the joint. But, using this method, it is difficult to obtain the dynamic modelling of the robot with several joints. The Euler-Lagrange formulation is described by the energy equilibrium equation which is more adapted in analysing the constraints of the links motion [19].

To develop the dynamic model of the studied mechanism, we will apply besides the Euler-Lagrange approach, the fundamental principles of dynamics and kinematics and the finite elements.

By using the total potential and kinetic energies denoted respectively by E_{pTot} and E_{cTot}, the Lagrangian is given by

$$L = E_{cTot} - E_{pTot} \tag{9}$$

According to [20], the Euler-Lagrange equations of motion is described by

$$\tau_n = \frac{d}{dt}\left(\frac{\partial L}{\partial q^{(1)}_j}\right) - \frac{\partial L}{\partial q_j} \tag{10}$$

Where, τ_n states the generalized torques vector at the robot joint, j is body index ($j = 1,2$), the vectors q_j and $q^{(1)}_j$ present, respectively, the joints angles and its velocities. From the Fig. 6, the positions of two points P_1 and P_2 placed respectively on the first rigid body and on the second flexible arm are given by

$$P_1 = x_1\vec{e}_{x1} \tag{11}$$

$$P_2 = l_1\vec{e}_{x1} + x_2\vec{e}_{x2} + y_2\vec{e}_{y2} \tag{12}$$

Its derivatives are respectively described as follows:

$$V_1 = x_1\dot{\theta}_1\vec{e}_{x1} \tag{13}$$

$$V_2 = \left[l_1\dot{\theta}_1 S_2 - y_2(\dot{\theta}_1 + \dot{\theta}_2)\right]\vec{e}_{x2} + \left[l_1\dot{\theta}_1 C_2 + \dot{y}_2 + x_2(\dot{\theta}_1 + \dot{\theta}_2)\right]\vec{e}_{y2} \tag{14}$$

where $S_2 = sin(\theta_2)$ and $C_2 = cos(\theta_2)$.

In all expressions, the trigonometric function $sin(q_i)$ is appointed by S_i and the trigonometric function $cos(q_i)$ is appointed by C_i.

In our work, it is assumed that the flexible body is divided into two elements and its lateral displacement is described by the B-spline functions [21], [22].

The joint angles and the nodal displacements identify the total degree of freedom of the system presented by

$$q = [\theta_1, \theta_2, q_{11}, q_{12}, q_{21}, q_{22}]^T \tag{15}$$

Where, q_{11} and q_{21} present respectively the nodal displacement related to the first node, q_{12} and q_{22} present respectively the nodal displacement related to the second node.

The calculation of kinetic and potential energies is performed from the elemental energies of each body. For the total kinetic energy E_{cTot}, it is evaluated as the sum of the kinetic energy of the rigid body and that of the flexible body. The general expression can be given by

$$E_{cTot} = \frac{1}{2}J_1\vec{w}_i\vec{w}_i + \frac{1}{2}\int_{r_i}^{l_i} m_i\vec{V}_i\vec{V}_i dx_i + \frac{1}{2}M_i\vec{V}_i\vec{V}_i\Big|_{x_i = l_i} \tag{16}$$

Where, w_i is the absolute angular speed of the system and V_i is the absolute speed of any point of the i^{th} body.

The kinetic energy of the rigid body T_1 can be deduced as follows:

$$T_1 = \frac{1}{2}\left[(1+f_{I_1})I_{R_1} + I_{M_1}\right]\left(q^{(1)}{}_1\right)^2 \tag{17}$$

Where,

$$I_{R_1} = \frac{1}{3}(l_1^3 - r_1^3)m_1 \tag{18}$$

$$I_{M_1} = M_1 I_1^2 \tag{19}$$

$$f_{I_1} = \frac{J_1}{I_{R_1}} \tag{20}$$

The flexible body can be presented by uniform Euler-Bernoulli beam [23]. The kinetic energy can be given by

$$T_2 = T_{2r} + T_{2f} \tag{21}$$

Where, T_{2r} is the kinetic energy of rigid part of the flexible arm and T_{2f} is the kinetic energy of the flexible part of this arm. The energy T_{2r} can be deduced as follows:

$$\begin{aligned} T_{2r} = {} & \frac{1}{2}\left[(l_2 - r_2)m_2 l_1^2 + M_2 l_1^2\right]\left(q^{(1)}{}_1\right)^2 \\ & + \frac{1}{2}\left[(1+f_{I_2})I_{R_2} + I_{M_2}\right]\left(q^{(1)}{}_1 + q^{(1)}{}_2\right)^2 \\ & + \frac{1}{2}\left[m_2 l_1\left(l_2^2 - r_2^2\right) + 2M_2 l_1^2\right]\left(q^{(1)}{}_1 + q^{(1)}{}_2\right)q^{(1)}{}_1 C_2 \end{aligned} \tag{22}$$

Where,

$$I_{R_2} = \frac{1}{3}(l_2^3 - r_2^3)m_2 \tag{23}$$

$$I_{M_2} = M_2 I_2^2 \tag{24}$$

$$f_{I_2} = \frac{J_2}{I_{R_2}} \tag{25}$$

According to the generalized coordinates, the energy T_{2f} can be deduced as follows:

$$\begin{aligned} T_{2f} = {} & \frac{1}{2}h^T M_{ff} h(q^{(1)}{}_1 + q^{(1)}{}_2)^2 + \frac{1}{2}h^{(1)T} M_{ff} h^{(1)} \\ & + (q^{(1)}{}_1 + q^{(1)}{}_2)\left[M_{fq_2}h^{(1)} - M_{fq_1} h l_1 q^{(1)}{}_1 S_2\right] \\ & + M_{fq_1}h^{(1)} l_1 q^{(1)}{}_1 C_2 \end{aligned} \tag{26}$$

Where, h and $h^{(1)}$ present the vectors of nodal variables of the elementary bodies of the flexible arm and the derivatives and M_{ff} deduced from the Hermite Spline Functions presents the mass matrix of the flexible part.

The total potential energy E_{pTot} can be composed of the strain energy U_a delivered by the centrifugal forces at a point on the Bernoulli's beam, the strain energy U_b due to deformation resulted by deflection, the energy U_c delivered by the engines and the potential energy U_g due to gravity. The energy U_a is deduced from

$$-dU_a = -\int_{r_2}^{l_2} R(x_2)\left(\frac{\partial y_2}{\partial x_2}\right) d\left(\frac{\partial y_2}{\partial x_2}\right) dx_2 \tag{27}$$

Where, $R(x_2)$ presents the axial load of a point of the Bernoulli beam located at x_2 and y_2 is the elementary displacement which can be expressed by

$$y_2(x,t) = \sum_{i=1}^{4} f_i U_i(t) \tag{28}$$

Where, ϕ_i is the Hermite Spline functions and $U_i(t)$ is the movement (rotation or translation) of resulted by each fictitious joint of the flexible arm [16]. The energy U_b can be expressed by

$$U_b = \frac{1}{2}\int_{r_2}^{l_2} E_2 I_2 \left(\frac{\partial y_2}{\partial x_2^2}\right)^2 dx_2 \tag{29}$$

Concerning the energy U_c, it is described by

$$U_c = -\sum_{i=1}^{2} u_i q_i \tag{30}$$

Where, u_i is the i^{th} input torque produced by the i^{th} actuator. Then, the energy U_g is given by

$$\begin{aligned} U_g = & \sum_{i=1}^{2}\left[\int_{r_2}^{l_2} m_2 y_2 dx_2 + M_2 y_2\Big|_{x_2=l_2}\right] g\cos(q_1+q_2) \\ & + \sum_{i=1}^{2}[m_i s_i h_i(q_1,q_2) + M_i H_i(q_1,q_2)]\vec{g} \end{aligned} \tag{31}$$

Where, according to the base, H_i presents the i^{th} body height and h_i is that of the gravity centre of the i^{th} body. Using the previous expressions, the Lagrangian can be deduced with respect to (9). Then, according to the joint variable vector with respect to the time, the derivatives of Lagrangian are deduced. In terms of generalized coordinates, the dynamic equation of the mechanism's model can be calculated and deduced as follows:

$$\begin{aligned} & [M + M_n(q) + M_a(q)]q^{(2)} + D_d q^{(1)} \\ & + \left[K + K_a(q,q^{(1)})\right]q + N(q,q^{(1)}) = Bu \end{aligned} \tag{32}$$

Where, the sum of the matrices M and $M_a(q)$ presents the inertia matrix due to rotation induced by the axial load where the first matrix is linear whereas the second is nonlinear, $M_n(q)$ presents the inertia matrix due to the additional rotation delivered by the axial load which is nonlinear, D_d presents the damping linear matrix, K presents the generalized geometric stiffness matrix which is nonlinear, $K_a(q,q^{(1)})$ presents the geometric stiffness matrix due to the rotation induced by the axial load which is linear, $N(q,q^{(1)})$ presents the sum of the vector of Gravity's torque and the vector of inertial forces with the second derivatives of the coordinates of the system which is nonlinear, B presents the input matrix and ending with u which presents the input torques delivered by the DC motors.

C. Linear Parameter Varying Approach for Dynamic Model

As shown in (26), the dynamic model of the studied system is nonlinear. This nonlinearity caused some problems which can be avoided using the linearization approach. However, this approach is available only in a delimited region and it does not consider the external perturbations. In order to remedy the limits of the linearization method, the LPV approach is applied to the differential equation of the rigid-flexible manipulator robot. Several approaches can be used the transformation of a nonlinear dynamic model into an LPV model [24], [25].

The PLV approach is defined as a linear time-varying system presented by its state-space matrices which are given by functions of some varying parameters. It consists of adopting some change of variable methodology which is based on function substitution for the LPV dynamic model of the studied mechanism. In general, the LLV dynamic model can be deduced by continuous-time state-space equations as follows:

$$\dot{x}(t) = A(\varphi(t))x(t) + B(\varphi(t))u(t) \tag{33}$$

$$y(t) = C(\varphi(t))x(t) + D(\varphi(t))u(t) \tag{34}$$

Where,

$$\varphi(t) \in \Theta, \forall t \geq 0 \tag{35}$$

Where, $y(t)$, $x(t)$ and $u(t)$ are respectively the outputs, the inputs and the states of the system, $A(\varphi(t)) \in \mathbb{R}^{n_x \times n_x}$, $B(\varphi(t)) \in \mathbb{R}^{n_x \times n_u}$, $C(\varphi(t)) \in \mathbb{R}^{n_y \times n_x}$ and $D(\varphi(t))$ are time-varying matrices depending to $\varphi(t)$ and Θ is the polygon of vertices detailing the limit values of the variable parameters.

In our work, the input output and feedforward matrices are invariant that is $B(\varphi(t)) = B_{tot}$ $C(\varphi(t)) = C_{tot}$ and $D(\varphi(t)) = 0$ can be considered. So, the particular form of LPV system of our model can be shortly presented as follows:

$$\dot{x}(t) = A_{lpv}(\varphi(t))x(t) + B_{tot}u(t) \tag{36}$$

$$y(t) = C_{tot}x(t) \tag{37}$$

Where, A_{lpv} presents matrix which depends on time-varying parameters given by

$$A_{lpv} = \begin{bmatrix} 0 & 0 & 1 & 1 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & \varphi_1(t) & \varphi_2(t) \\ 0 & 0 & \varphi_3(t) & \varphi_4(t) \end{bmatrix} \tag{38}$$

Each variable parameter of the vector $\varphi_i(t)$ and its time-derivative vary between known extremal values: $\varphi_i(t) \in [\underline{\varphi}_i, \overline{\varphi}_i]$ and $\dot{\varphi}_i(t) \in [\underline{\dot{\varphi}}_i, \overline{\dot{\varphi}}_i]$.

IV. Numerical Simulations and Discussion

The rigid-flexible manipulator robot is installed in the laboratory of robotics in the University Polytechnic of Catalonia (UPC) in Spain presented as follows in Fig. 6.

After obtaining the LPV dynamic model, for several motions profiles, the torque will be applied to each joint of the robot. Table 1 summarizes the numerical values of parameters of the studied mechanism.

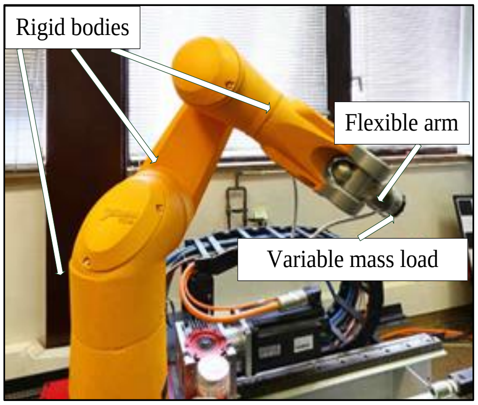

Fig. 6. Rigid-flexible manipulator robot.

TABLE I. DYAMIC PARAMETERS

Parameter	Unit	Value
E_1	GPa	71
E_2	GPa	196
$I_1 = I_2$	m^4	$1.67\,10^{-12}$
$m_1 = m_2$	Kg / m	0.831
$r_1 = r_2$	m	0.05
$J_1 = J_2$	$Kg.m^2$ / rad	0.05
$L_1 = L_2$	m	0.375
M_1	Kg	0.05
M_2	Kg	$(0.05)^2$
M	Kg	0.01

In our work, the perturbation is presented by the mass load variation and the initial value of this variable is announced in the previous table.

In order to illustrate the validity of the LPV dynamic model of the rigid-flexible manipulator system and effectiveness of the motion profiles in presence of the parameter perturbation, we perform the simulation in MATLAB using a PID controller considering the parameters of Table 2. The parameters of PID controller are chosen by varying manually and gradually its values in order to obtain the best tracking of the robot at the reference.

TABLE II. PID CONTROLLER PARAMETERS

Parameter	Unit	Unit
K_{P1}	_	500
K_{I1}	_	1
K_{D1}	_	10^{-3}
N_1	_	50

D. With Trapezoidal Profile as Input

In the first case, let apply the trapezoidal motion profile as input to the redundant manipulator robot then the mass load is increased in order to evaluate the system behaviour in presence of disturbance as shown in Fig. 7. We can note that the input discontinuity in one hand and in the other hand the mass load variation has an important impact on the studied system, especially on its flexible structure.

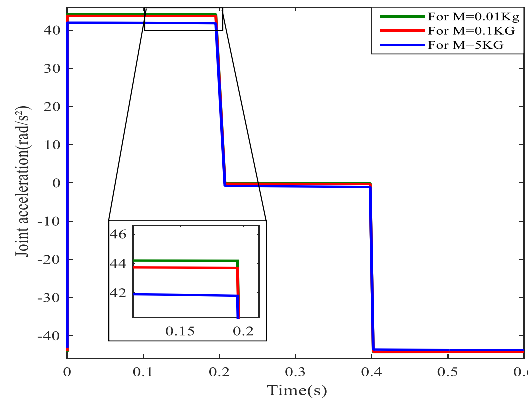

Fig. 7. Torque for trapezoidal profile applied to each joint.

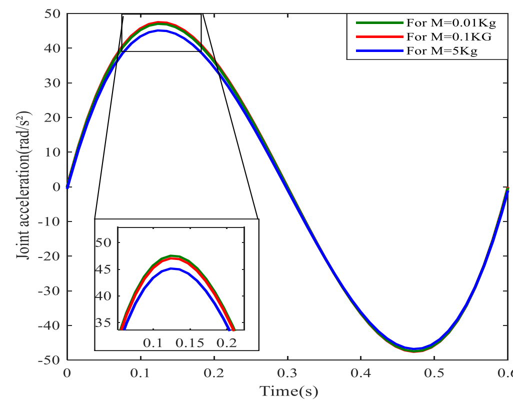

Fig. 8. Torque for fifth-degree polynomial profile applied to each joint.

E. With Fifth-Degree Polynomial Profile as Input

In another case, a fifth-degree polynomial profile is applied as input along the time period of movement of 0.6 seconds. Fig. 8 shows that this profile keeps the continuity in form of this motion however it does not retain its sign.

With a variable mass load M, it is clear that increasing M lead to a higher difference between input and system response as D_a increases. From this, it can be deduced that a variation of M and D_a is proportional.

F. With Eighth-Degree Polynomial Profile as Input

Using the same period time of the previous case, the eighth-degree polynomial profile is used to test the system performances in presence of disturbance described by a variable mass load (Fig. 9).

This profile is characterized by the parameter I_{nd} which allows having the smoothest trajectory. In our work, this smoothest trajectory is maintained in $I_{nd} = 1.452$.

After applying several tasks with variable mass load, more the mass load increases more the error between the desired trajectory and the system output increases.

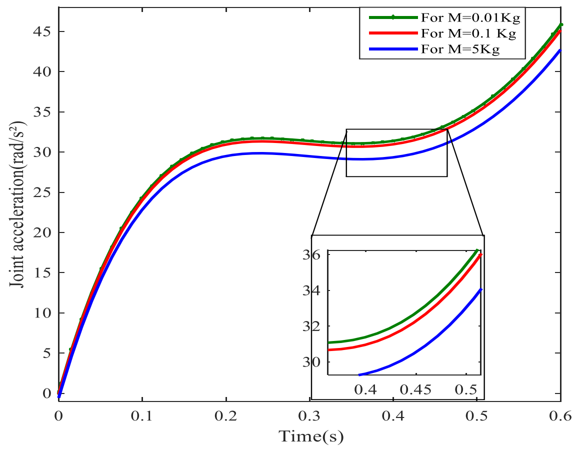

Fig. 9. Torque for eighth-degree polynomial profile applied to each joint.

V. Conclusion

This paper focuses on the simulation of a redundant manipulator robot. For this purpose, this robot is dynamically modelled using the LPV approach by applying several motions profiles. These inputs are characterized by a continuous torque in minimum time.

The contribution of this paper relies on evaluating the system behaviour by adding to the external perturbation created by the flexible structure of its second arm an external vibration provided by the discontinuous torque applied to the system in a first test and then adding a smooth torque as a motion profile. An improvement in the system performance is obtained through the choice of motion profile characterized by the torque continuity and the movement smoothness.

The results with several tasks demonstrate the effectiveness of the smooth motions profiles and the robustness of LPV modelling using variable mass load as an external distribution.

The future work will be interested in the synthesis of a command that takes into account the flexibility structure of the robot on the one hand and on the other by the input smoothness.

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A Novel Algorithm to Improve Resolution for Very Few Samples

Sidi Mohamed Hadj Irid
STIC Laboratory, Faculty of Technology
University of Tlemcen, BP119 Chetouane
Tlemcen, Algeria

Samir Kameche
STIC Laboratory, Faculty of Technology
University of Tlemcen, BP119 Chetouane
Tlemcen, Algeria

Abstract—**This paper presents a new technic to improve resolution and direction of arrival (DOA) estimation of two closed source, in array processing, when only few samples of received signal are available. In these conditions, the detection of sources (targets) is more arduous, and even breaks down. To overcome these problems, a new algorithm is proposed. It combines spatial smooth method to widen the spatial resolution, bootstrap technique to estimate increased sample size, and a high resolution technique which is Multiple Signal Classification (MUSIC) to estimate DOA. Through different simulations, performance and effectiveness of the proposed approach, referred to as Spatial Smooth and Bootstrapped technique "SSBoot'', are demonstrated.**

Keywords—Direction of arrival (DOA) estimation; Bootstrap; Multiple Signal Classification (MUSIC); resolution; spatial smoothing; array processing; Uniform Linear Array (ULA)

I. Introduction

When two sources are very close in space in the ambiguity range, the radar detects them like one target. The spatial resolution limits for two closely spaced sources in the context of array processing is still an active research [1]-[3]. In fact, there has been a tremendous involvement in the investigation of how DOA estimation of many closed source (targets) can be estimated. Most of them, [4], [5], are based on high resolution methods, e.g. Multiple Signal Classification (MUSIC) or Estimation of Signal Parameter via Rotational Invariance Technique (ESPRIT), and detect sources using eigenvalues obtained from covariance matrix of samples. However, the main issue of high resolution method for DOA's estimation is predetermination of the model order, since these techniques requires imperatively number of sources, as input parameter within estimation. This estimation is based on information theoretic criteria like AIC (AKAIKE) and Rissanen's minimum description length criterion (MDL) algorithms to estimate DOA of sources [2], [5]-[7].

In other hand, performance of these techniques stays very poor for low samples, low SNR, correlated source signals and presence of impulsive white noise. To improve the resolution, a spatial smoothing technique is used. This technique divides the array into multiple overlapping sub-arrays. In each sub-array, the correlation matrix is estimated from bootstrapped data samples. We exploit the idea of the author in [3] and applied MUSIC in each sub-array; to estimate the number of sources as number of peaks [1], [8], [9].

Unfortunately, the most existing methods are less efficient and lost large performance or even breakdown when only few samples of received signal are available. To reduce this hurtful effect and improve the robustness of the covariance estimator, a robust non-parametric bootstrap method estimator was proposed [10]-[13]. Based on time random sampling of original data, to estimate its sampling distribution without any model assumption.

In this work, a new algorithm is proposed. It combines spatial smoothing, a high resolution method (MUSIC) and Bootstrap technique to estimate closely spaced number of sources and their DOA's when only few samples of received signal are available. First, it's used bootstrap method to estimate the covariance matrix, then spatial smoothing curves up the antenna array into L sub-networks. In each sub-network, MUSIC algorithm allows to estimate the number of closely spaced sources and their DOA's. Numerical simulations are given to assess the performance of the used technique.

The paper is organized as follows. Data, array model and MUSIC description are introduced in Section 2, followed by spatial sampling model description in Section 3. Then bootstrap technique is presented in Section 4. The proposed algorithm "SSBoot" is described in Section 5. Simulation results are given in Section 6. Finally, discussion and conclusion are given in Section 7.

II. Problem Formulation

Just to simplify the notation, we assume a Uniform Linear Array (ULA) composed of M sensors, with equip-spacing $d=\lambda/2$ as shown in Fig. 1; where λ is the wavelength of the source signal. Consider a K narrowband far-field uncorrelated source impinging on the array with ($M > K$), such that sources have a direction of arrival (DOA) θ_k, with k=1... K.

A. Array Signal Model

The received snapshots at this array, at instance t are given by [1], [14].

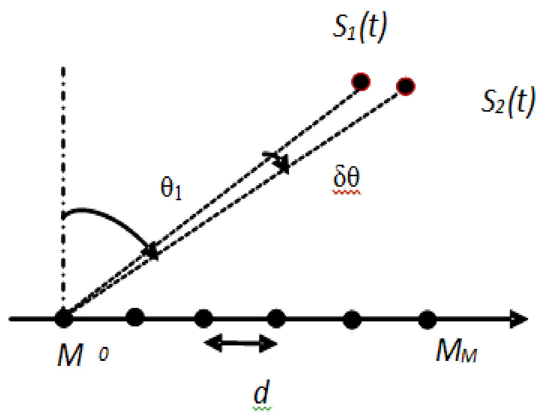

Fig. 1. Localization of two closely spaced sources impinging on ULA.

The received signal corrupted by additive white Gaussian noise is presented at instance t by mathematical equation [1], [15], [16]:

$$y(t) = A\,s(t) + n(t) \tag{1}$$

Where

$$A = [a_1 \ldots a_{1k}]^T \tag{2}$$

is the steering matrix (MxK) full rank,

$$a_k = \left[1 \;\; a_k^1 a_k^2 \ldots a_k^{(M-1)}\right]^T \tag{3}$$

and each column is written in function of the received signal as follows:

$$a_k = e^{(-j\,2\pi (d/\lambda)\sin\theta_k)} \tag{4}$$

$$y(t) = [y_1(t) \;\ldots\; y_M(t)]^T \tag{5}$$

$$S(t) = [S_1(t) \;\ldots\; S_K(t)]^T \tag{6}$$

$$n(t) = [n_1(t) \;\ldots\; n_M(t)]^T \tag{7}$$

Superscript $(.)^T$ presents the transpose operation. Where $y_k(t)$ denotes the output of k^{th} sensors, $s_q(t)$ source signal and $n_k(t)$ is a stationary noise model, temporally white, zero-mean Gaussian random process independent of the source signals. The covariance of received data is [1], [17], [18]:

$$R_{yy} = E\left[Y.Y^H\right] = AR_S A^H + \sigma^2 I \tag{8}$$

Where

$$R_S = E\left[S(t)S^H(t)\right] \tag{9}$$

The superscript $(.)^H$ stands for the conjugate transposition, σ^2 is variance and I indicate the identity matrix.

Furthermore, the covariance matrix is estimated by [2], [3], [17], [18]:

$$R_{yy} = \frac{1}{N} Y.Y^H \tag{10}$$

The eigenvalues are given as follows:

$$\rho_1 \geq \rho_2 \geq \ldots \geq \rho_k \geq \rho_{k+1} = \rho_M = \sigma^2$$

where the first K eigenvalues belong to the source signal, and the last (M-K) to the noise.

MUSIC plots the pseudo-spectrum [2], [19]:

$$V_{Music} = \frac{1}{a^H(\theta) E_n E_n^H a(\theta)} \tag{11}$$

Where En is the (Mx(M-K)) noise subspace composed of the eigenvectors associated with the noise.

If we assume two closely spaced source where their DOA are θ_1 and θ_2 such as:

$$\theta_1 = \theta_2 + \delta\theta \quad \text{with } \delta\theta \prec 5°$$

B. Spatial Smoothing

In this section, it's described the use of spatial smoothing in proposed algorithm in order to improve resolution of very close spaced sources. The ordinary spatial smooth consists of dividing the whole array into L sub-arrays shifted one another by one sensor; the rest of sensors are overlapped as shown in Fig. 2. It estimates the correlation matrix as the average of all correlation matrices from the sub-arrays $\hat{R}^l$ and can be represented as:

$$\hat{R} = \frac{1}{L} \sum_{l=1}^{l=L} \hat{R}^l \tag{12}$$

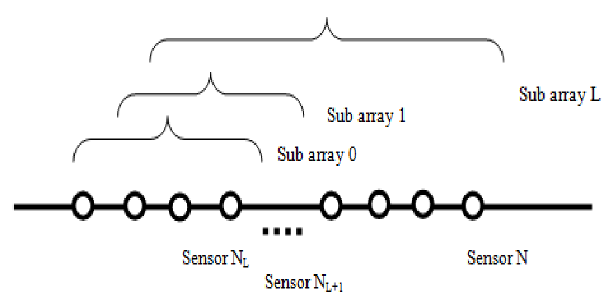

Fig. 2. An ULA antenna is divided into L sub array.

Our method is based on representations of Abed-Meraim et al. in [7] who divided the whole array into interleaving sub-arrays. In each sub-arrays the received signal is given by:

$$Y_m = \begin{bmatrix} y_1(0) & \cdots & y_1(T) \\ y_2(0) & \cdots\cdots & y_2(T) \\ . & & . \\ . & & . \\ y_{((N_L-1))}(0) & \cdots\cdots & y_{((N_L-1))}(T) \end{bmatrix} \quad (13)$$

Where m is ( )th array and varies from 1 to L, and N_L= M/L.

The same, the steering matrix for the m array is given by:

$$A_m(\theta) = \begin{bmatrix} 1 & \cdots & 1 \\ e^{j\pi\sin\theta_1} & \cdots & e^{j\pi\sin\theta_q} \\ e^{j\pi 2\sin\theta_1} & \cdots & e^{j\pi 2\sin\theta_q} \\ . & & . \\ . & & . \\ e^{j\pi(N_L-1)\sin\theta_1} & \cdots & e^{j\pi(N_L-1)\sin\theta_q} \end{bmatrix} \quad (14)$$

Where T is a snapshot number and q is the number of source signal received in each sub-array.

In this case, and unlike results of Abed-Meraim in [3], [19], we are sure that number of sensors is always greater than number of sources, and therefore it respects the assumption to apply MUSIC.

Thus, that spatial smoothing or spatial sampling considerably improves the resolution. Indeed, according to (13) and (14), the angular part in the matrix output are multiplied by a factor (NL-1) which is greater than 1. Therefore, the angular separation is widened and the resolution is improved.

C. Bootstrap Replication

In this section, non-parametric bootstrap resampling techniques are presented, designed for independent and identically distributed data. However, the assumption of iid data can break down during operation either because data are not independent or because data are not identically distributed [7], [8].The original data points:

$$\mathrm{x} = (\mathrm{x}_1, \mathrm{x}_2, \mathrm{x}_3 \ldots . \mathrm{x}_n) \quad (15)$$

with probability $\frac{1}{n}$ for each sample.

A bootstrap sample X* is obtained through replacement of original data points by random sampling (n times) [10]-[12].

Some bootstrap samples can be:

$$\mathbf{x}^{(1)} = (\mathrm{x}_2, \mathrm{x}_5, \mathrm{x}_n \ldots . \mathrm{x}_1)$$
$$\mathbf{x}^{(2)} = (\mathrm{x}_1, \mathrm{x}_4, \mathrm{x}_1 \ldots . \mathrm{x}_n)$$
$$\mathbf{x}^{(B)} = (\mathrm{x}_1, \mathrm{x}_4, \mathrm{x}_1 \ldots . \mathrm{x}_n) \quad (16)$$

with n samples.

We assume that the x_i's are independent identically distributed (iid), each having distribution F. Bootstrap proposes to resample from a distribution chosen to be close to F in some sense. This could the empirical distribution$\hat{F}$, resampling from $\hat{F}$is referred to as non-parametric bootstrap [10].

At the end we obtain:

$$\boldsymbol{X}^* = (x_1^*, x_2^*, x_3^*, \ldots . x_n^*) \quad (17)$$

Herein, we create a number B of resamples $\mathrm{X}_1^*, \ldots, \mathrm{X}_\mathrm{B}^*$. The resampled boostrapis an unordered collection of n samples points drawn randomly from X with replacement, so that each X_i^*has probability $\frac{1}{n}$of being equal to any one of the X_j' s. In other terms [8], [9], [11]:

$$\text{Prob}\left[X_i^* = X_j / X\right] = n^{-1},\ 1 \le i,\ j \le n \quad (18)$$

This means that $\boldsymbol{X}^*$ is likely to contain repeats. The probability that a particular value x_i is left out is

$$P = (1 - \tfrac{1}{n})^n \quad (19)$$

We exploits the resample bootstrap algorithm described in [9] to reproduce samples and use it in our proposed "SSBoot" algorithm.

III. Spatial Smooth Bootstrapped "Ssboot" Algorithm

Firstly, the proposed method is based on increasing the number of snapshots received on array network using bootstrap technique. Secondly, each of sub-arrays is processed separately and finally the average DOA estimation is considered.

Determination number of sources first is essential for high-resolution method. It should use AIC or MDL algorithm to determine the model order. But, in this work, we followed the same spirit given in [3], [7]. We estimated the source number using beamforming or Capon method applied to the global array output. If q peaks appear, we re-apply MUSIC algorithm by restricting our research in intervals around each q peaks.

Applying spatial smoothing yields to divide the array network into L overlapping sub-arrays thus, we obtain L different DOA's estimates. Among these L sets, we keep only the highest number of peaks in each interval.

Our new algorithm, we named "SSBoot" can be summarized as follows:

- *Step 1*: Applying bootstrap technique to generate new samples by sampling with replacement of original data.
- *Step 2*: First estimation number of sources on global array network using Capon method.
- *Step 3*: Defining set of intervals where search are refined.
- *Step 4*: Divide the global antenna array into L shifted overlapped sub-arrays.
- *Step 5*: On each sub-array, we apply MUSIC Algorithm. The number of MUSIC spectrum peaks equals to number of sources.

- *Step 6*: The number of sources is selected from p intervals for L sub-arrays that present maximum number peaks,
- *Step 7*: Computing the final DOA, after sorting and calculating the average from each interval and selecting sub-arrays with maximum peaks.

$$\widehat{\theta_J} = \frac{1}{p}\sum_{l=1}^{p}\widehat{\theta_J^l} \qquad (20)$$

Where $\widehat{\theta_J^l}$, l =1..p represents p estimates DOA from different sub-arrays.

IV. Simulation and Result

To illustrate the performance of the proposed method, some numerical results are presented to analyse and compare behaviour estimation of the new proposed algorithm which is named "SSBoot". A Uniform Linear Array (ULA) is constituted of N=10 sensors spaced of half-length wave length is employed. Assume that there are two closely spaced uncorrelated narrowband signal sources with the same wavelength λ, θ_1= 32° and θ_2= θ_1+$\delta\theta$, where $\delta\theta$ is a very small angle difference. Simulation results were obtained based on 1000 Monte Carlo simulation.

Performance of bootstrap for varying snapshots for arrival angles of -40° -20° 60° and 80° respectively, are illustrated in Fig. 3. When a few samples (20 snapshots) are received the MUSIC spectrum response is almost flat and the DOA is difficult to extract, but when these samples are bootstrapped at 200, 1000 the 2000 samples, the responses increases and the peaks become noticeable. However, it demonstrates the effectiveness of the bootstrap method to improve the detection and estimation of DOA.

Fig. 4 presents the probability of target detection in percentage for various angular separations; it illustrates the performance achieved by our method for few snapshots with low SNR. In fact, for received low samples, the detection is weak; it increases slowly when SNR increases. But when these samples are bootstrapped at 1000 snapshots the estimation rate improves and reaches the maximum rate with low SNR. However, our algorithm SSBoot bootstraps the received samples and uses the spatial sampling to improve its estimation performance for the same number of snapshots. Indeed the very close spaced sources are detected for low SNR.

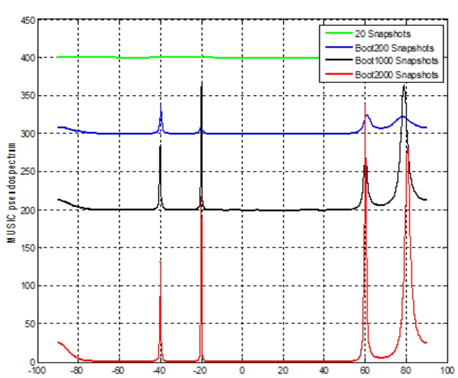

Fig. 3. MUSIC Spectrum for various snapshots.

Fig. 5 depicts the probability of detection rate in percentage for various SND in dB; it shows that for few samples the detection nearly breaks down. With bootstrap at 1000 snapshots, the detection is slightly achieved because of low SNR values. The SSBoot proposed method overcame this limitation by ensuring a highest detection rate for low SNR and very close separation sources.

Fig. 6 illustrates, the DOA's MSE (Mean Square Error) vs. SNR for L=2, and angle difference $\delta\theta$ =5°, it can be observed that the MSE for Only bootstrapped MUSIC method and our technique SSBoot that uses Bootstrap, spatial smooth and MUSIC have almost the same estimation accuracy. It means that SSBoot improves the resolution with no estimation accuracy enhancement.

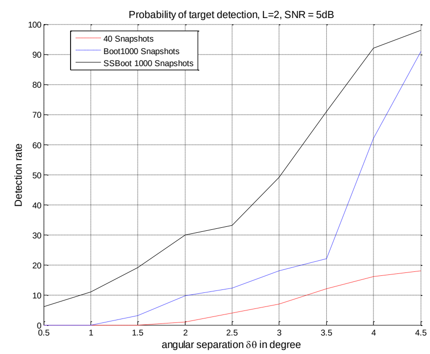

Fig. 4. Angular separation vs. detection rate.

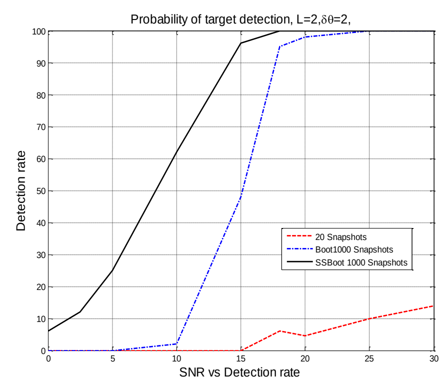

Fig. 5. SNR vs. Detection rate.

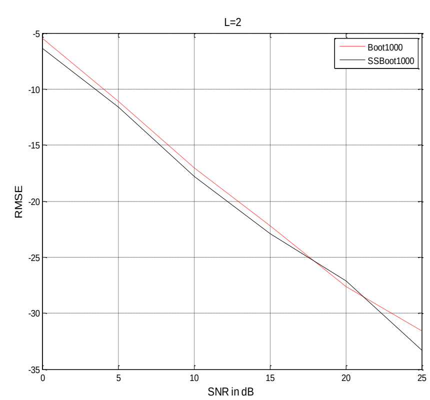

Fig. 6. RMSE vs. SNR.

V. CONCLUSION

In this paper, we have introduced a new technique based on the combination of bootstrap technique, spatial smoothing and MUSIC method to improve resolution and the estimation of closed source number. It was shown that for the case of small sample size, the bootstrap technique is used to estimate and evaluate the resample data. The spatial smoothing was also presented as spatial sampling method, which provides different sub-arrays and widens the angle separation of closed source when MUSIC Algorithm is applied.

The results presented in this paper prove that our method is attractive when few samples are available and outperforms the ordinary technique at difficult scenarios especially for very close source and low SNR. Simulations have shown that spatial sampling and bootstrap techniques outperforms DOA estimation, when MUSIC method is applied for small sample size and very close sources. But it's demonstrated that SSBoot technique can't improve the estimation accuracy.

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Modeling House Price Prediction using Regression Analysis and Particle Swarm Optimization

Case Study: Malang, East Java, Indonesia

Adyan Nur Alfiyatin
Faculty of Computer Science
Brawijaya University, Malang, Indonesia

Hilman Taufiq
Faculty of Computer Science
Brawijaya University, Malang, Indonesia

Ruth Ema Febrita
Faculty of Computer Science
Brawijaya University, Malang, Indonesia

Wayan Firdaus Mahmudy
Faculty of Computer Science
Brawijaya University, Malang, Indonesia

***Abstract*—House prices increase every year, so there is a need for a system to predict house prices in the future. House price prediction can help the developer determine the selling price of a house and can help the customer to arrange the right time to purchase a house. There are three factors that influence the price of a house which include physical conditions, concept and location. This research aims to predict house prices based on NJOP houses in Malang city with regression analysis and particle swarm optimization (PSO). PSO is used for selection of affect variables and regression analysis is used to determine the optimal coefficient in prediction. The result from this research proved combination regression and PSO is suitable and get the minimum prediction error obtained which is IDR 14.186.**

Keywords*—*House prediction; regression analysis; particle swarm optimization

I. INTRODUCTION

Investment is a business activity that most people are interested in this globalization era. There are several objects that are often used for investment, for example, gold, stocks and property. In particular, property investment has increased significantly since 2011, both on demand and property selling [1]. One of the increasing of property demand is because of high population in Indonesia. Indonesian Central Bureau of Statistics states that in East Java 50% of the population of East Java classified as a young population who have age approximately at 30 years old [2]. The result of this census indicates that the younger generation will need a house or buy a house in the future. Based on preliminary research conducted, there are two standards of house price which are valid in buying and selling transaction of a house that is house price based on the developer (market selling price) and price based on Value of Selling Tax Object (NJOP). According to Lim, et al the fundamental problem for a developer is to determine the selling price of a house [3]. In determining the price of home, the developer must calculate carefully and determine the appropriate method because property prices always increase continuously and almost never fall in the long term or short [4].

There are several approaches that can be used to determine the price of the house, one of them is the prediction analysis. The first approach is a quantitative prediction. A quantitative approach is an approach that utilizes time-series data [5]. The time-series approach is to look for the relationship between current prices and prevailing prices. The second approach is to use linear regression based on hedonic pricing [6], [7]. Previous research conducted by Gharehchopogh, et al. [7] using linear regression approach get 0,929 error with the actual price. In linear regression, determining coefficients generally using the least square method, but it takes a long time to get the best formula.

Particle swarm optimization (PSO) is proposed to find the coefficients aimed at obtaining optimal results [8]. Some previous researches such as Marini and Walzack [9], [10] show that PSO gets better results than other hybrid methods. There are several advantages of PSO, in the small search space PSO can do better solution search [11]. Although the PSO global search is less than optimal [12], but on the optimization problem the value of the variable on the regression equation can find a maximum solution using PSO [12], [13].

This research aims to create a house price prediction model using regression and PSO to obtain optimal prediction results. PSO is used for selection of affect variables in house prediction, regression is used to determine the optimal coefficient in prediction. In this study, researchers wanted to know the performance of the developed model in time series data. Prediction house prices are expected to help people who plan to buy a house so they can know the price range in the future, then they can plan their finance well. In addition, house price predictions are also beneficial for property investors to know the trend of housing prices in a certain location. This research is focused in Malang City, because Malang is one of tourism and urban city in East Java.

II. RELATED WORK

A. House Price Affecting Factors

There are several factors that affect house prices. In his research Rahadi, et al. [14] divide these factors into three main groups, there are physical condition, concept and location. Physical conditions are properties possessed by a house that can be observed by human senses, including the size of the house, the number of bedrooms, the availability of kitchen and garage, the availability of the garden, the area of land and buildings, and the age of the house [15], while the concept is an idea offered by developers who can attract potential buyers, for example, the concept of a minimalist home, healthy and green environment, and elite environment.

Location is an important factor in shaping the price of a house. This is because the location determines the prevailing land price [16]. In addition, the location also determines the ease of access to public facilities, such as schools, campus, hospitals and health centers, as well as family recreation facilities such as malls, culinary tours, or even offer a beautiful scenery [17], [18]. In general, the factors affecting the house prices will be presented in Table 1.

TABLE I. HOUSE PRICE AFFECTING FACTORS

Literature	**Physical condition**							**Concept**	**Location**				
[15] (Limsombunchai, 2004)		√		√		√	√		√	√		√	
[18] (Jim and Chen, 2009)		√					√	√					√
[17] (Kisilevich, Keim and Rokach, 2013)												√	√
[16] (Zhu and Wei, 2013)									√	√	√	√	√
[14] (Rahadi, et all, 2015)	√	√	√	√	√		√	√	√	√	√	√	√
[19] (Bryant, 2016)	√	√		√	√								

B. Hedonic Pricing

Hedonic pricing is a price prediction model based on the hedonic price theory, which assumes that the value of a property is the sum of all its attributes value [20]. In the implementation, hedonic pricing can be implemented using regression model. Equation 1 will show the regression model in determining a price.

$$y = a.x_1 + b.x_2 + \cdots + n.x_i \qquad (1)$$

Where, y is the predicted price, and x_1, x_2, x_i are the attributes of a house. While a, b, ... n indicate the correlation coefficients of each variables in the determination of house prices.

III. DATA SET

In this research, we use house price data based on NJOP from Land and Building Tax (PBB) payment structure. Due to limited access to the data, this study used 9 houses data in time series scattered in Malang City area, within 2014-2017. Normalization of data is done by completing the empty data at a certain time with the assumption that land prices tend to change every 2 years, while building prices tend to be stable.

The data tabulation offer information of the houses includes: home id, address (street name), longitude-latitude, year, building area, land area, NJOP building price (IDR/m^2), NJOP land price (IDR/m^2), distance from city center(km), amount number of campuses, amount number of restaurants, amount number of health facilities, amount number of playground, amount number of schools, amount number of traditional markets or malls, amount number of worship places, and also easiness access to public transportation. The city center in this study defined as the location of the square of Malang City. The distance to city center is calculated using Google maps. Meanwhile, easy access to public transportation is calculated between radius 400 meter. The calculation of nearest objects in the certain radius using buffering techniques accessed through the site http://obeattie.github.io/.

IV. RESEARCH METHODOLOGY

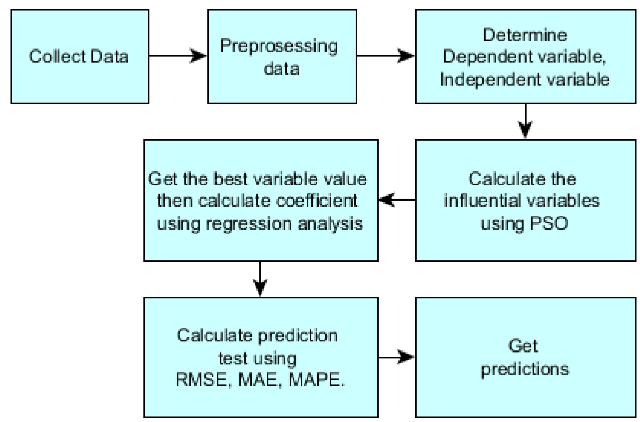

Fig. 1. Diagram flow research.

Based on Fig. 1, the process of regression analysis and particle swarm optimization methods is described in the following section:

A. Regression analysis

The prediction model used in this research is hedonic pricing, the suitable model using regression, with the standard formula as shown in (1). The dependent variable symbolized as Y is NJOP price and independent variables with symbol x_1- x_{14} consist of year, building area, land area, NJOP land price (IDR/m^2), NJOP building price (IDR/m^2), distance to center of the city, amount number of campuses, amount number of restaurants, amount number of health facilities, amount number of amusement parks, amount number of educational facilities, amount number of traditional markets, amount number of worship places, and easiness to public transportations is shown in (2).

$$NJOP = a.building\ area + b.land\ area + \cdots + n.public\ transportation \qquad (2)$$

In this case, the public transportation variable will be 0 or 1, 0 means no public transport passes the area within 200 meters. And 1 means that there is public transports which passes through the area.

B. Particle Swarm Optimization (PSO)

PSO is a stochastic optimization method that represents solutions as particle [21]. Amount number of particles are generated randomly, where each particle consists of some dimensions of *xi* position and velocity *vi*. Each particle will measure its fitness value which shown in (3).

$$f(x) = \varepsilon \text{ from prediction} \tag{3}$$

Where, *f (x)* is the fitness value of each particle that indicates the error prediction value. Each particle will explore the solution search space to get optimal results. The displacement from one position to another is greatly influenced by the speed of each particle, to obtain the best position required a dynamic speed formulation using (4) [22].

$$v_i^{t+1} = w.v_i^t + c_1 . r_1 (p_i - x_i) + c_2 . r_2 (pg_i - x_i) \tag{4}$$

Where, *vi* shows the velocity value for the particle dimension to *i* to *n*, *t* denotes the iteration time, *w* is the value of the inertia vector whose value is obtained dynamically using (5) [23]. p_i is the best position ever obtained for each particle, while the pg_i is the best position ever achieved by the whole particle. c_1 and c_2 sequential are cognitive and social constant, which in this study is 2.5 and 0.5. r_1 and r_2 are 0.5 and 2.5. Once obtained speed will be updated position using (6).

$$W = (w\max - w\min)\frac{iterasi-t}{iterasi} + w\min, \tag{5}$$

$$x_i^{t+1} = x_i + v_i^{t+1}, \tag{6}$$

In the PSO, too fast particle displacement position can make the method fail to obtain the optimum solution. This problem can be handled by performing speed control or velocity clamping [9]. The speed control mechanism by conducting conditions for the speed of each particle uses (7).

$$\text{if } (v_{ij}^{t+1} > v_j^{max}) \text{ then } v_{ij}^{t+1} = v_j^{max}$$
$$\text{if } (v_{ij}^{t+1} < v_j^{min}) \text{ then } v_{ij}^{t+1} = v_j^{min}, \tag{7}$$

While, the value of $\mathbf{v_j^{max}}$ is generated using equation 8 and $\mathbf{v_j^{min}}$ is the negative value of $\mathbf{v_j^{max}}$.

$$\text{Vj max} = k\,\frac{(x_{j,\max} - x_{j,\min})}{2} + k \in [0,1] \tag{8}$$

Calculation cycle of velocity values *vi* and updated position *xi* will be repeated until maximum iteration is achieved. When the iteration is over, the best particles come out as the optimum solution.

C. Testing Methods

The model developed in this research will be tested using several methods such as Mean Absolute Percentage Error (MAPE), Mean Absolute Error (MAE), and Root Mean Square Error (RMSE). MAPE is calculated by making an average percentage of the absolute error of each predicted result. Thus, MAPE can indicate how much prediction error. MAPE is described in (9).

$$MAPE = \frac{100}{n}\sum_{t=1}^{n}\left|\frac{x_t - y_t}{x_t}\right| \tag{9}$$

MAE calculate the average of absolute error for each predicted result. MAE is useful when measuring errors in certain units. MAE values can be calculated using (10).

$$MAE = \frac{\sum_{i=1}^{n}|y_i - x_i|}{n} \tag{10}$$

RMSE is used to calculate predicted performance by considering the prediction error of each data. RMSE formula can be seen there (11).

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(d_i - p_i)^2} \tag{11}$$

V. Experiment and Result

The experimental process examines the parameters used on particle swarm optimization such as particle test, iteration test, and also inertia weight combination test.

The PSO algorithm generates population and initial velocity in the range of [0-100]. The range used has been tested from the number -1000 to 1000 and obtained that range 0-100 can provide highest fitness solutions. Particle test and iteration test for each model use a multiple of 100 in which the maximum particle test lies in 3000 particles, if the particles tested over 3000 require longer computation time. For each testing run 5 times, and the fitness value obtained from the average test results. The last test was a combination of inertia weight, performed to know the displacement velocity of each particle, inertia weight is tested in a range [0,1-0,9]. The result of each parameter testing is shown in Table 2.

TABLE II. Test Result of Parameter

M	Test Particles	Fitness	Iteration Test	Fitness	Inertia weight		Fitness
1	1800	39950.9474	700	186.704	0.8	0.4	2420.86
2	1800	825.9134	1900	45242.522	0.2	0.7	86434.266
3	500	139.68	1800	814.624	0.3	0.8	298492.2
4	2000	201506.91	500	69.38	0.2	0.7	2.126
5	2500	539040.066	1900	124.27	0.3	0.9	243.902
6	800	214060.584	600	297389.054	0.4	0.7	846.26
7	1900	236999.218	1800	581.986	0.4	0.9	388.75

M-1 represents Karang Besuki area, M-2 represents Tunggulwulung area, M-3 represents Lowokwaru area, M-4 represents Puncak Trikora area, M-5 represents Sumbersari area, M-6 represents Dinoyo area, and M-7 represents Manggar area. The experimental result shows that the fitness value based on data being tested. Furthermore, this research is better using more data.

After knowing the result of parameter testing, error values are calculated based on RMSE, MAE, and MAPE. Comparison of test values is shown in Table 3.

TABLE III. RESULT OF TESTING METHOD

Methods	Accuracy		
	MAPE	***MAE***	***RMSE***
Regression	4.84552	4.84552	2201253
Regression - PSO			
Model 1	0.73255	2837.2	14186
Model 2	0.0238	5520.95	44168
Model 3	0.02251	16635.9	99816
Model 4	5.84929	16798.2	67193
Model 5	0.42763	44950.7	179803
Model 6	0.07718	34153.1	170765
Model 7	0.0932	19830.8	79323

VI. CONCLUSION

In this paper, several tests have been performed using linear regression and particle swarm optimization methods to perform house price prediction. Based on the NJOP data of 9 houses, the system is modeling house price predictions into 7 models each of them represents one area. The area modeling includes Kelurahan Karang Besuki, Tunggulwulung, Lowokwaru, Puncak Trikora, Sumbersari, Dinoyo, Manggar. Based on the result from particle test, iteration test and inertia weight test can be concluded that M-1 represents Karang Besuki area get the best parameter for optimal prediction. Those best values of parameters obtained are 1800 particles, 700 iterations and of inertia weight 0.4 and 0.8 can get minimum prediction error RMSE as IDR 14.186. For the other model, the error prediction values are still large. Using different methods that match the time-series data will be used in the future research to obtain smaller error prediction values and using more data to get the better result.

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Area k-Coverage Optimization Protocol for Heterogeneous Dense Wireless Sensor Networks

Hervé Gokou Diédié
Université Niangui Abrogoua
Abidjan 02 BP 801, Côte d'Ivoire

Boko Aka
Université Niangui Abrogoua
Abidjan 02 BP 801, Côte d'Ivoire

Michel Babri
Institut National Polytechnique Félix Houphouët-Boigny
Yamoussoukro BP 1093, Côte d'Ivoire

***Abstract*—Detecting redundant nodes and scheduling their activity is mandatory to prolong the lifetime of a densely-deployed wireless sensor network. Provided that the redundancy check and the scheduling phases both help to preserve the coverage ratio and guarantee energy efficiency. However, most of the solutions usually proposed in the literature, tend to allocate a large number of unnecessary neighbor (re)discovery time slots in the duty-cycle of the active nodes. Such a shortcoming is detrimental to battery power conservation. In this paper, we propose a crossing points-based heuristic to fast detect redundant nodes even in heterogeneous networks; then, an integer linear program and a local exclusion based strategy to respectively, formulate and solve the sensing unit scheduling problem. Simulations show that the resulting localized asynchronous protocol outperforms some state-of-the-art solutions with respect to coverage preservation and network lifetime enhancement.**

Keywords*—*Coverage; optimization; wireless sensor network; scheduling; GRASP

I. Introduction

Wireless sensor networks (WSNs) are composed of small electronic resource-limited devices that are capable to measure physical quantities in their environment. To collect information in remote or hostile areas, such networks require a random deployment of large number of nodes. However, this high node density leads to a redundantly monitored Field of Interest (FoI) that favors energy wastes and decreases network lifetime. Therefore, it is mandatory to work towards detecting and turning off all redundant nodes while preserving the area coverage ratio required by the underlying application.

Solutions for this kind of redundancy check are often categorized into deterministic and probabilistic ones [1]. Deterministic methods require that nodes have an exact knowledge of their positions whereas probabilistic ones try to relax this constraint.

As for putting redundant nodes to sleep state, it requires scheduling their duty-cycle. Techniques that are often used for that purpose can also be categorized into deterministic and probabilistic ones. Deterministic solutions are based on self-inactivation or sequential activation techniques. Whereas, probabilistic ones use more or less complex probability laws to calculate states transitions durations.

The above-mentioned coverage optimization processes lead to two well-known NP-hard problems, namely, the *minimum set cover problem* [2], [3] and the *sleep scheduling problem* [4]. Most of the solutions usually proposed for the first process have relatively good accuracy and precision ratios. While solutions for the second process tend to allocate a large number of unnecessary neighbor (re)discovery time slots in the duty-cycle of the active nodes. Such a shortcoming causes message overhead.

In this paper, we use a crossing points-based technique to detect redundant nodes in heterogeneous networks. Then, we formulate the scheduling problem as a special case of the general Maximum Set Packing problem using an integer linear program.

We propose a local mutual exclusion based scheduling scheme from a metaheuristic referred to as GRASP (Greedy Randomized Adaptative Search Procedure) that helps to reduce active nodes' *neighbor discovery frequency* and balance their energy depletion. The resulting asynchronous localized protocol increases network lifetime and preserve the coverage ratio. A second contribution of this paper is a sleep scheduling strategy that takes into account energy wastes due to state transition.

The rest of the paper is organized as follows. In Section II, we review some major related solutions recently proposed in the literature. Then, we detail our contribution in Section III. We evaluate its performance by analysis and simulation in Section IV. The results we obtained are discussed in Section V. Finally, we conclude the paper in Section VI.

II. Related Work

Coverage optimization in WSNs consists of two steps, namely, redundancy detection and sensing unit sleep scheduling. In this paper, we focus on area k-coverage, i.e. we assume that the underlying application requires that every points in the Field of Interest (FoI) be covered by at least k sensors. Where $k \geq 1$.

A. Redundancy Check

Area coverage redundancy check is generally reduced to the minimum set cover problem which was proven to be NP-hard [2], [3]. Existing solutions can be categorized into deterministic and probabilistic ones [1]. The former are often geometric and use techniques, such as *virtual grid* [5], *sponsored sector* [6], *perimeter-coverage* [7], *intersection points* [8], *voronoï tessellation* [9]. Unfortunately, they require that nodes have an exact knowledge of their location. While probabilistic methods try to relax this constraint.

Liu *et al.* [10] proposed the use of a virtual grid. To this end, each sensor node divides its coverage into virtual square grids. If all these grids are covered by its neighbors a node is said to be redundant. Virtual grid technique has a low time complexity but are often space consuming. Chenait *et al.* [11] suggest the use of the sponsored sector technique. Each node has to create three sectors with a $\frac{2\pi}{3}$ central angle and check if each of them is covered by at least k neighbors. However, they applied this strategy only on a homogeneous network. Chen *et al.* [12] chose the perimeter-coverage scheme to evaluate the k-coverage of sensors. These nodes have to verify that each arc it shares with its neighbors is totally covered. Gupta *et al.* [13] used a similar approach for heterogeneous 3D networks. Unfortunately, when using this strategy, each node needs to have at least three neighbors. Jabeur *et al.*[14] proposed a dynamic strategy referred to as *bully approach* where sensor-nodes must compete to offer their services and get rewarded. In the relocation scheme, nodes with low *actual redundancy* force sensors with high *actual redundancy* to be the redundant sensors. This strategy requires that nodes be able to control their mobility. Xing *et al.* [8] proposed the intersection points method. A node is redundant if all the crossings inside its sensing disk are covered. However, this strategy was applied using an algorithm with a $\mathcal{O}(n^3)$ time complexity. Moreover, Liu *et al.* [15] showed that the above strategy is based on a necessary but not sufficient criterion. Diédié *et al.* [16] gave an additional condition to this technique. It consists in building the Maximal Redundancy Zone of each node, namely the convex hull of all crossings. Therefore, a node is redundant if it is located inside this zone and the above mentioned condition is met. Chang *et al.* [17] use the *weighted voronoï diagram* method. Weight metric is based on nodes residual energy. In order to minimize coverage redundancy, each node has to build its *voronoï cell* and adjust its sensing range while avoiding *holes*.

There are also several probabilistic solutions in the literature. They are based on probabilistic sensing models [18], [19]. Each node must find a condition that helps the area under its surveillance be also covered by at least k neighbors with a probability greater than a predefined threshold. Gupta *et al.* [20] proposed to use a probabilistic scheme in a heterogeneous network. Yang *et al.* [21] showed a relationship between two points in FoI implying that if one of them is covered with a probability greater than a value denoted by εe^{kd} the other one is covered with a probability no less than ε. The problem is formulated as an integer linear program and solved with a greedy approximation solution. Tian *et al.* [22] proposed a solution based on a sensing model derived from the Neyman-Pearson theory [23]. Unfortunately, the strategy is not fully-distributed since it is initialized by a central node.

B. Sleep Scheduling

Sensing unit scheduling is the second phase of the coverage optimization process. Solutions to this problem can also be categorized into deterministic and probabilistic ones.

Deterministic solutions are based on *self-inactivation* or *sequential activation* techniques [1]. When using the first method, each sensor node has to discover its neighborhood and perform redundancy check then enters into Sleep state, if it is redundant. To help mitigate coverage hole probability, a redundant node has to start a random backoff timer. After the latter timer expiration, it broadcasts a SLEEP message then enters into Sleep state if it has not already received such a message. Among the recent authors that use this technique are Idrees *et al.* [24], Jamali and Hatami [25], Zhang *et al.* [26], Gupta *et al.* [13] and Shi *et al.* [27].

However, when using sequential activation approach, nodes are mostly-off, set a timer and become active with a certain probability. If redundant, they broadcast ACTIVE message before entering into Sleep state. If a node receives a ACTIVE message it adjusts its timer and perform redundancy check. Zhang and Hou [28] are among the first authors who used that technique. Recently, He *et al.* [29] or More and Wagh [30] also applied such a strategy.

Probabilistic scheduling solutions are based on states transitions of which durations are chosen using more or less complex Probability laws. The state transition is similar to the one used by *sequential activation* strategy. Dioungue and Thiare [31] used the Weibull distribution to select all the *sentinels* i.e. nodes that should wake up and remain active when all their neighbors are in sleep state. Shen *et al*. [32] proposed to define sleep state's duration using exponential law. However, the process used to calculate the required node average density is costly. Farinelli *et al*. [33] used an agent-based Learning Automata strategy to help sensor-nodes to coordinate their sense/sleep schedules. Authors proposed a linear program to find a schedule that maximizes the total utility (i.e. social welfare) of agents.

III. Proposed Solution

A. Motivation and Objectives

This work is aimed at energy efficiency and coverage ratio preservation. To this end, redundancy check process must be precise and accurate while being executed regularly from fresh information. Strategy often used consists in merging redundancy check and neighbor discovery into a single process. However, this approach is costly when applied with *self-inactivation* or *sequential activation* sleep scheduling techniques, as discussed in the previous section. Indeed, nodes have to check their redundancy each time they receive respectively a SLEEP and a ACTIVE message; hence, a large number of time slots is allocated for unnecessary neighbor (re)discovery processes in the duty-cycle of active nodes. Moreover, many redundancy checks are based on old information. Such shortcomings increase message overhead and the risk of having coverage holes.

Our goal is to minimize unnecessary redundancy check and neighbor discovery periods. We also aim at providing a strategy to define a Sleep schedule that helps to balance the amount of energy expended during states transitions.

B. Assumptions

We make the following assumptions:

- For each sensor u, we have $r_c(u) = 2{\times}r_s(u)$ where $r_c(u)$ et $r_s(u)$ are respectively its communication and sensing ranges.

- Nodes have knowledge of their positions using localization schemes similar to the ones discussed by Holger and Willig [34] or Mao and Fidan [35].

- Network is heterogeneous i.e. nodes have different ranges; since they have different residual energy and are able to adjust their communication ranges.

- This process takes place in the plane.

C. Description

We detail in this section our protocol referred to as CGSCP (Coverage Greedy Scheduling Coordination Protocol). It consists of two phases: redundancy check and sensing unit sleep scheduling.

D. Redundancy Check

We give some important definitions for a better understanding of our strategy.

Definition 1 (Redundancy)**.** *A node u is redundant with respect to a subset of neighbors denoted by N_i if the area denoted by $cov(u)$ that u covers is identical with or included inside the area denoted by $cov(v)$ obtained from the union of all areas covered by each member v of N_i. Formally, u is redundant with respect to N_i iff $cov(u) \subseteq \bigcup_{v \in N_i : N_i \subseteq N(u)} cov(v)$. Where $N(u)$ denotes the set of node u's neighbors.*

Definition 2 (m-redundancy)**.** *A node u is m-redundant if it is redundant with respect to at least m subsets of neighbors.*

Definition 3 (Maximum Redundancy Zone)**.** *The Maximum Redundancy Zone (MRZ) is the region delimited by the convex hull deriving from the cloud of the intersection points between a subset of neighbors, as depicted by Fig.1. Points located on this hull will be referred to as **Border Points**; whereas the others will be referred to as **Interior Points**.*

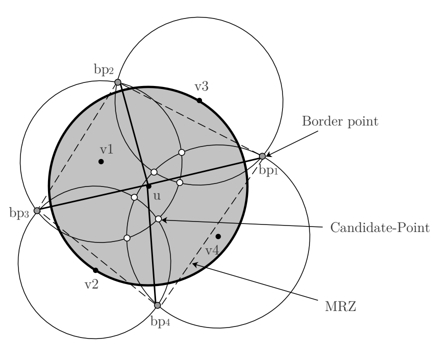


Fig. 1. The Maximum Redundancy Zone (MRZ) of node u deriving from the intersection points between its neighbors v_1, v_2, v_3 and v_4.

Area k-coverage problem has been proven to be NP-hard [36]. Therefore,we have to design an approximated solution.

Each node must apply the following intersection points-based heuristic in order to check its redundancy.

- Step 1: Discover the vicinity and select neighbors.

- Step 2: If no neighbor found then not redundant, stop. Instead, if at least two neighbors found go to Step 4.

- Step 3: If located inside this neighbor then redundant, otherwise not redundant, stop.

- Step 4: Derive the MRZ from neighbors' intersection points.

- Step 5: If not located inside the MRZ then not redundant, stop.

- Step 6: If at least one border point is covered then not redundant, stop.

- Step 7: If covered by one neighbor and the latter is adjacent to all the other neighbors then redundant, stop.

In the example shown in Fig. 1 node u is redundant with respect to neighbors v_1, v_2, v_3 and v_4 since u is located inside the MRZ, it does not cover any border point and it is covered by neighbors v_1 and v_4. Each of them are adjacent to the other neighbors.

It is noteworthy to mention that Steps 5 and 6 can be combined. To this end, node has to derive its RMRZ (Relative MRZ) from the set of points composed of its position, the intersection points with its neighbors and their mutual crossing points. Therefore, node is outside the MRZ if its position or at least one of the intersection points with its neighbors is on the RMRZ.

Methods we use to determine intersection points' coordinates and to construct nodes' RMRZ are detailed in our previous work [16].

We propose to estimate each node u's k-coverage by assessing its m-redundancy. Therefore, we have to search its vicinity denoted by $N(u)$, for $m (m \geq k)$ subsets of neighbors with respect to which node u is redundant. This problem can be formulated using the following program:

$$\max m \tag{1}$$

$$st: \bigcup_{i=1}^{m} N_i \tag{2}$$

$$(d(u,p) \leq r_s(u)) \Rightarrow (\exists v \in N_i, d(v,p) \leq r_s(v)) \tag{3}$$
$$, \forall p \in A, \forall i = 1, ..., m$$

$$(|N_i| \leq |N_j|) \Rightarrow (|N_i \cap N_j| < |N_i|), \tag{4}$$
$$i, j \in [1, m], \; i \neq j$$

Our goal is (1) i.e. finding the number of subsets of neighbors denoted by m that satisfies the constraints expressed by (2) - (4).

Equation 2 requires that only node u's neighbors are concerned. Whereas (3) helps ensuring that node u is redundant with respect to each of these subsets; i.e. any point p in the area of interest A covered by u $(d(u,p) \leq r_s(u))$ must also be covered by at least a member v of subset N_i. Equation 4 requires more detailed explanations. Indeed, it means that when a subset of nodes is involved in a redundancy case, its members must not be inserted into another subset. For instance, if node u is redundant with respect to subsets $N_1 = \{1, 3, 7\}, N_2 = \{1, 5, 7, 3\}$ and $N_3 = \{1, 7, 4\}$, N_2 will be ignored since it includes N_1. In other words, u is not redundant with respect to N_2 because it is already redundant with respect to N_1. Instead, N_3 can be included in a feasible solution since it has only two elements in common with N_1.

We must relax (4) since we are solving the m-redundancy problem in order to evaluate nodes'k-coverage. Hence, we replace (4) by (5). The latter requires that the subsets of neighbors be disjoint.

$$N_i \cap N_j = \emptyset \,, i, j \in [1, m] \,,\ i \neq j \tag{5}$$

Therefore, area k-coverage problem becomes similar to a well-known NP-hard problem referred to as *General Maximum Set Packing* [2], [37]. We formulate it with an integer linear program.

$$x_{ij} = \begin{cases} 1 & \text{if neighbor } i \text{ is inserted into subset } j, \\ 0 & \text{otherwise} \end{cases} \tag{6}$$

$$y_i = \begin{cases} 1 & \text{if redundant with respect to subset } i \\ 0 & \text{otherwise} \end{cases} \tag{7}$$

Note that for $n\,(n \geq 1)$ neighbors, there are at most n disjoint subsets of neighbors.

$$\max \sum_{i=1}^{n}\sum_{j=1}^{n} x_{ij} + \sum_{j=1}^{n} y_j \tag{8}$$

$$st: \ \sum_{i=1}^{n} x_{ij} \ \leq \ 1, \forall j = 1, ..., n \tag{9}$$

$$\sum_{j=1}^{n} y_j \ \geq \ k \tag{10}$$

$$x_{ij} \in \{0, 1\} \ \ \forall i = 1, ..., n, \forall j = 1, ..., n \tag{11}$$

$$y_j \in \{0, 1\} \ \ \forall j = 1, ..., n \tag{12}$$

Equation 8 is the objective-function. Equation 9 assures that a neighbor is inserted into only one subset. Equation 10 requires that the number of subsets with respect to which the node is redundant, be greater than or equal to k.

To solve this problem, we use a scheme based on a metaheuristic referred to as **GRASP (Greedy Randomized Adaptative Search Procedure)**, proposed by Feo and Resende [38], [39]. The latter scheme is formally detailed in Algorithms 1 - 3.

Algorithm 1 Evaluation of node u's k-coverage

Input: $k, nitrmax,\ N(u), p$
Output: s^*
$s^* \leftarrow \emptyset$
$c^* \leftarrow 0$
$nitr \leftarrow 0$
$RCL \leftarrow \emptyset$ ▷ Restricted Candidate List
while $(k > |s^*|) \wedge (N(u) \neq \emptyset) \wedge (nitr < nitrmax)$ **do**
  $s \leftarrow$ Generate random greedy solution $(N(u), p, RCL)$
  $s \leftarrow$ Local Search(s) ▷ Neighbouring solutions of s*
  $c \leftarrow f(s)$ ▷ Calculate cost see Eq.8
  if $(\, c^* < c)$ **then**
    $s^* \leftarrow s$
    $c^* \leftarrow c$
  end if
  $nitr \leftarrow nitr + 1$
end while
return s^*

Algorithm 2 Greedy random solution generation by node u

Input: $N(u), p, LRC$
Output: s^*
$n \leftarrow 0$
repeat
  Choose randomly $e \subseteq N(u)\ : 1 \leq |e| \leq |N(u)|$
  if Redundancy-Check(e) **then** ▷ see Algorithm 1
    $LRC \leftarrow LRC \cup \{e\}$
    $N(u) \leftarrow N(u) \setminus e$
    $n \leftarrow n + 1$
  end if
until $(n = p) \vee (N(u) = \emptyset)$

Sort in ascending order the LRC ▷ According to length
$s^* \leftarrow \{e \in LRC \mid\ \nexists f \in LRC : |e| < |f|\}$
return s^*

Algorithm 3 Local search by node u

Input: $s^*, N(u), p$
Output: s^*
$s \leftarrow \{e \in s^* |\ \nexists f \in s^* : |e| > |f|\}$ ▷ get the smallest element
$n \leftarrow 0$
OK $\leftarrow$ **false**
while $(n < p) \wedge (N(u) \neq \emptyset) \wedge \neg$OK **do**
  Choose randomly $e \subseteq N(u)\ : 1 \leq |e| \leq |N(u)|$
  if Redundancy-Check(e) **then** ▷ see Algorithm 1
    $s^* \leftarrow s^* \setminus s$
    $s^* \leftarrow s^* \cup \{e\}$
    $N(u) \leftarrow N(u) \setminus s$
    OK $\leftarrow$ **true**
  end if
  $n \leftarrow n + 1$
end while
return s^*

E. Sleep Scheduling

The second phase of CGSCP consists in scheduling the sensing unit's activity. We formulate it as a *local mutual exclusion problem* [40], i.e. a localized version of the well-known mutual exclusion problem [41], [42], [43]. Indeed, we believe that a node enters into the *critical section* when it begins to check its redundancy. *Redundancy* is a relative notion that has a local scope as *Sleep scheduling*.

Our mutual exclusion scheme aims at minimizing the number of active nodes while preserving the coverage degree required by the underlying application. In other words, preventing coverage *holes* by avoiding two redundancy-dependent nodes to enter into Sleep state simultaneously.

We propose an heuristic-based solution since scheduling problem also was proven to be NP-hard [4].

Definition 4 (**Node's state**). *Any node u can only have the following states :*

- *Active(**ACT**)* ,
$state(u) = ACT \iff [(r_s(u) > 0) \wedge (\nexists v \in N(u) : state(v) = SLP)]$
- *Discovery (**DSC**)* ,
$state(u) = DSC \iff [(r_s(u) > 0) \wedge (\nexists v \in N(u) : state(v) = DSC \vee state(v) = FRZ)]$

- *Frozen (**FRZ**)* ,
$state(u) = FRZ \iff [(r_s(u) > 0) \wedge (\exists v \in N(u) : state(v) = SLP)]$
- *Sleep (**SLP**)*
$state(u) = SLP \iff [(r_s(u) = 0) \wedge (\breve{N}(u) \neq \emptyset)]$

Where $N(u)$ and $\breve{N}(u)$ respectively denote the set of node u's one-hop neighbors and the family of subsets involved in its k-coverage.

Our sensing unit scheduling scheme is actually based on the *k*-coverage evaluation process as described in the previous section. Indeed, once deployed, each node must choose its next neighbor discovery and *k*-coverage evaluation time randomly and uniformly in interval $[t_{min}; t_{max}]$, then start a back-off timer. When the latter expires, node enters into Discovery state and broadcasts a HELLO message. Each neighbor should reply with a WELCOME message containing its residual neighborhood discovery time denoted by Δt_{discov}. A node v in Discovery state returns to Active state when receiving a HELLO message from a neighbor u with a greater ID. Therefore, after updating its neighbor table, and checked that it is k-redundant, node u must calculate its sleep time duration denoted by t_{sleep} using (13). If the latter is greater than a threshold denoted by th_{sleep}, node u has to send a SLEEP message that includes its t_{sleep} to a subset of neighbors with respect to which it is k-redundant. This subset is the one with the lowest cardinality chosen among the m subsets discovered by the redundancy check process. th_{sleep} is defined so as to overcome delays and the amount of energy expended during states transitions.

In (13) Er , Ei, $\breve{N}$ and N respectively denote nodes' residual energy, their initial energy, the family of subsets with respect to which they are redundant and their neighbors set.

$$t_{sleep} = \widetilde{t} - \Big((\alpha \times \frac{Er}{Ei}) + (\beta \times (1 - \frac{|\breve{N}|}{|N|})) + \gamma\Big) \qquad (13)$$

α and β, γ are three weighting coefficients such as $\alpha+\beta = 1$ while γ is randomly chosen in interval $[0, 1-(\alpha+\beta)]$. $\widetilde{t}$ is the lowest Δt_{discov} provided by the neighbors with respect to which a node is redundant.

It is worth noting that $\widetilde{t}$ must take account of the average message response time denoted by t_{reply}.

When a node u in Active state receives a SLEEP message from a neighbor v, it resets its next neighbor discovery time and enters into Frozen state. Node u has to postpone its next discovery time by $(t_{sleep}(v) - t_{reply})$ units of time, if its residual discovery time denoted by $\Delta t_{discov}(u)$ is lower than neighbor v's sleeping time, namely, $t_{sleep}(v)$.

It is also noteworthy to mention that after receiving a SLEEP message a node in Frozen state must increase by 1 unit its *fixation counter* denoted by δf. The latter is helpful for nodes to count neighbors that are in Sleeping state.

At the end of its sleeping time, a node enters into Active state, chooses at random its next neighbor discovery time and broadcast a AWAKE message to its one-hop neighbors. After receiving such a message, nodes in Frozen state have to decrease their *fixation counter* by 1 unit and enter into Active state if their fixation counter's value reaches 0. The sensing unit scheduling process is formally described in Algorithms 4 and 5. States transitions are depicted in Fig. 2.

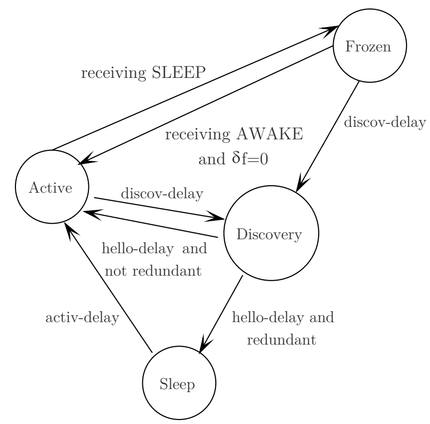


Fig. 2. State transition diagram of CGSCP.

Algorithm 4 Sensing unit scheduling by node u

Input: *Ethr*, t_{reply},α,β,γ,$\widehat{r}_s$, $t_{min}, t_{max}, th_{sleep}$

```
Er ← Estimate residual energy
ACTIV-delay ← 0
while (Er > Ethr) do                          ▷ Residual energy is enough
    if (ACTIV-delay = 0)∨(Current-Time() = ACTIV-delay) then
        r_s(u) ← r̂_s
        state(u) ← ACT
        t_discov(u) ← U(t_min; t_max)           ▷ Uniform Law
        DISCOV-delay ← Current-Time() + t_discov(u)
        δf ← 0
        Send AWAKE to v, ∀v ∈ N̆(u)
    end if
    if (Current-Time() = DISCOV-delay) then     ▷ Critical Section
        state(u) ← DSC
        Choose Δt_discov(v) : ∀v, w ∈ N(u) ⇒ (Δt_discov(v) > Δt_discov(w))
        Δt_discov(u) ← U(t_min; t_max) + Δt_discov(v)
        DISCOV-delay ← Current-Time() + Δt_discov(u)
        HELLO-delay ← Current-Time() + t_reply
        Broadcast HELLO (id_u, Δt_discov(u), state(u))
    end if
    if (Current-Time() = HELLO-delay) then
        state(u) ← ACT
        Check k-coverage(N(u))                  ▷ see Algorithm 1
        if (N̆(u) ≠ ∅) then
            t_sleep(u) ← Sleeptime (α,β,γ,Er, Ei)   ▷ see Eq. 13
            if (t_sleep(u) > th_sleep) then
                N̂(u) ← min(N̆(u))
                Send SLEEP(t_sleep(u)) to v, ∀v ∈ N̂(u)
                r_s(u) ← 0
                state(u) ← SLP
                ACTIV-delay ← Current-Time() + t_sleep(u)
            end if
        end if
    end if
    Handle Scheduling messages                  ▷ see Algorithm 5
    Er ← Estimate residual energy
end while
```

Algorithm 5 Scheduling messages Handling by nœud u

1: **Receive** $message$ de v
2: **switch** $message$ **do**
3: **case** HELLO
4: **if** $(state(u) = ACT) \vee (state(u) = FRZ) \vee ((state(u) = DSC) \wedge (id_v > id_u))$ **then**
5: $\Delta t_{discov}(v) \leftarrow \Delta t_{discov}(v) - t_{reply}$ ▷ Considering latency
6: $N(u)\leftarrow$ Neighbor table Update $(id_v, \Delta t_{discov}(v), state(v))$
7: $\Delta t_{discov}(u) \leftarrow$ Current-Time() - *DISCOV-delay*
8: **Send** WELCOME $(id_u, \Delta t_{discov}(u), state(u))$ to v
9: **end if**
10: **if** $(state(u) = DSC) \wedge (id_v > id_u)$ **then**
11: $state(u) \leftarrow ACT$
12: **end if**
13: **case** WELCOME
14: **if** $(state(u) = DSC)$ **then**
15: $\Delta t_{discov}(v) \leftarrow \Delta t_{discov}(v) - t_{reply}$ ▷ Considering latency
16: $N(u)\leftarrow$ Neighbor table Update $(id_v, \Delta t_{discov}(v), statut(v))$
17: **end if**
18: **case** SLEEP
19: **if** $(state(u) \neq FRZ) \wedge (\Delta t_{discov}(u) < t_{sleep}(v))$ **then**
20: *DISCOV-delay* $\leftarrow$Current-Time() + $(t_{sleep}(v) - t_{reply})$
21: $state(u) \leftarrow FRZ$
22: **end if**
23: $\delta f \leftarrow \delta f + 1$
24: **case** AWAKE
25: **if** $(state(u) = FRZ)$ **then**
26: $\delta f \leftarrow \delta f - 1$
27: **if** $(\delta f = 0)$ **then**
28: $state(u) \leftarrow ACT$
29: **end if**
30: **end if**
31: **end switch**

IV. Performance Evaluation

To verify and validate our protocol we analyzed its time and messages number complexities. Then we formally proved its mutual exclusion property. We also conducted extensive simulations using OMNeT++ 4.6 simulator [44]. The results were compared to those obtained with some related protocols namely, CCP by Xing *et al.* [8] DiLCO by Idrees *et al.* [24], ERPC by Liu *et al.* [15], the solution by Gupta *et al.* [13] and VGSCA by Liu *et al.* [10] .

Theorem 1 (**Time complexity**). *On an asynchronous fair daemon, in the worst case and in the absence fault, the time complexity of CGSCP is* $\mathcal{O}(n)$.

Proof: In the worst case, topology induced by the network is a complete graph with n nodes and where each of them has $n - 1$ neighbors. In the worst case, a node u will randomly choose the greatest neighbor discovery time denoted by $t_{discov}(u)$. Therefore, before the latter occurs, it may receive at most $n-1$ SLEEP messages from its neighbors. After receiving a SLEEP message from a redundant neighbor v, node u will enter into Frozen state for at most $t_{sleep}(v) - t_{reply}$ units of time if v has chosen a sleeping time denoted by $t_{sleep}(v)$ that postpones node u's neighbor discovery time (see Lines 18 - 23 in Algorithm 5). Moreover, each node has to define its next neighbor discovery time according to those of its neighbors (see Lines 15 - 18 in Algorithm 4). In other words, nodes' waiting time before entering into the critical section and their sleeping time duration are linearly dependent on the number of their neighbors. Hence the $\mathcal{O}(n)$ time complexity. ■

Theorem 2 (**Message complexity**). *On an asynchronous and fair daemon, in the worst case and in the absence of fault, message number complexity of CGSCP is* $\mathcal{O}(n)$ *where* n *denotes the number of neighbors.*

Proof: In the worst case, topology induced by the network is a complete graph. Since each of the n nodes has $n - 1$ neighbors, CGSCP requires three messages namely, HELLO, SLEEP and AWAKE sent by a redundant node u to respectively, discover its neighborhood, announce its Sleep state and announce its Active state. Node u will receive $n-1$ WELCOME messages in response, hence $\mathcal{O}(n^2)$ messages in the worst case for n redundant nodes. ■

Lemma 1 (**Safety**). *Two redundancy-dependent nodes cannot discover their neighborhood, or enter into Sleep state simultaneously. More formally, let* $G = (V, E)$ *be the graph induced by network ; where* V *and* E *respectively denote the set of nodes and the set of links,* $\forall u, v \in V : \forall v \in N(u), ((state(u) = DSC) \vee (state(u) = SLP)) \Rightarrow ((state(v) = FRZ) \vee (state(v) = ACT))$.

Proof: Proving that nodes have an exclusive access to the critical section consists in showing that two adjacent nodes u and v $(v \in N(u) \wedge u \in N(v))$ cannot discover their neighborhood, let alone enter into Sleep state simultaneously. Indeed, if node u chooses a shorter next neighborhood discovery time denoted by $t_{discov}(u)$, it will certainly enter into Discovery state $(state(u) = DSC)$ before its neighbors.

Therefore, when node v receives a HELLO message, it will not enter also into discovery state (see Lines 3 - 12 in Algorithm 5). However, we could have $t_{disc}(u) = t_{disc}(v)$ for two nodes u and v because neighbor discovery times are randomly chosen; but, since their respective IDs namely, id_u and id_v are different $(id_u \neq id_v)$, it follows that $state(u) \neq state(v)$. Indeed, let us assume that $id_u > id_v$; after sending a HELLO message, node u will receive WELCOME messages in response and will evaluate its redundancy (see Lines 20 - 22 in Algorithm 4 and Lines 3 - 9 in Algorithm 5). In contrast, v will enter into Active state ($state(v) = ACT$ see Lines 10 - 12 in Algorithm 5). Therefore, node u would probably be the only node to enter into Sleep State $(state(u) = SLP)$ (see Lines 23 - 31 in Algorithm 4). Consequently, only node u's redundancy-dependent neighbors $(\widehat{N}(u))$ will finally be in Frozen state $(state(v) = FRZ)$ after receiving its SLEEP message (Lines 18 - 23 in Algorithm 5). Formally, $\forall v \in \widehat{N}(u), state(v) = FRZ$ and $\widehat{N}(u) \subseteq N(u)$ then $\forall v \in N(u), ((state(u) = DSC) \vee (state(u) = SLP)) \Rightarrow ((state(v) = FRZ) \vee (state(v) = ACT))$ ■

Lemma 2 (**Liveness**). *Each node will eventually discover its neighborhood or enter into Sleep state.*

Proof: Proving liveness consists in showing that any node can enter into another state after a finite length of time particularly, after been in Frozen state, even if a sleeping neighbor fails. Indeed, according to Lemma 1 after it had randomly chosen its next neighbor discovery time denoted by $t_{disc}(u)$ a node u will always enter into the critical section if $t_{disc}(u)$ is the shortest discovery time and its ID is the smallest after breaking tie. Therefore, two situations may occur:

- Node u is not redundant, it will update its neighborhood table and choose another neighbor discovery time denoted by $t_{discov}(u)$.

To this end, u chooses $t_{discov}(u) : \forall v \in N(u), t_{disc}(u) > \Delta t_{disc}(v)$ (see Line 15 Algorithm 4). Where $\Delta t_{disc}(v)$ is the residual time before node v's next neighbor discovery. This information was piggybacked in the WELCOME message that neighbor v sent to node u. The latter cannot prevent anymore its neighbors to also enter into critical section;

- Node u is redundant, therefore it enters into Sleep state ($state(u) = SLP$) and set its sleeping state time duration denoted by $t_{sleep}(u)$ according to the shortest neighbor discovery time and the threshold denoted by th_{sleep} . Formally, $t_{sleep}(u) : \forall v \in N(u), th_{sleep} < t_{sleep}(u) < \Delta t_{disc}(v)$. If $t_{sleep}(u)$ cannot meet this condition, node u will return immediately to Active state ($state(u) = ACT$). Instead, if node u can enter into Sleep state, its redundancy-dependent neighbors will enter into Frozen state. (see Lines 18 - 23 in Algorithm 5) $\forall v \in \widehat{N}(u), state(v) = FRZ$. The latter will return to Active state ($state(v) = ACT$) after receiving a AWAKE message sent by node u at the end of its sleeping time. In the worst case, nodes that are in Frozen state ($state(v) = FRZ$) will return to Active state when their neighbor discovery time occurs. In other words, let $G = (V; E)$ be the graph induced by the network, where V and E denote respectively the set of nodes and the set of links. Formally, $\forall u \in V, (\Delta t_{disc}(u) = 0) \Rightarrow (state(u) = ACT)$. ■

Lemma 3 (Concurrency). *Two redundancy-independent nodes can discover their neighborhood or enter into Sleep state simultaneously.*

Proof: Proving concurrency consists in showing that two non-adjacent nodes u and v ($v \notin N(u) \wedge u \notin N(v)$) can enter into their critical section freely with no conflict. Therefore, two events may occur:

- Nodes u and v have at least one neighbor in common ($N(u) \cap N(v) \neq \emptyset$). If their neighbor discovery times respectively denoted by $t_{disc}(u)$ and $t_{disc}(v)$ are such that $t_{disc}(u) > t_{disc}(v)$ and if we have $(state(u) = SLP) \Rightarrow (\exists w \in N(u) \cap N(v) : (state(w) = FRZ))$, node v will enter into its critical section freely ($state(v) = DSC \vee state(v) = SLP$) without node w having to enter into another state. The same event occur if we have $((t_{disc}(u) = t_{disc}(v)) \wedge (state(u) = SLP) \wedge (state(v) = SLP) \Rightarrow (\exists w \in N(u) \cap N(v) : (state(w) = FRZ))$;

- Nodes u and v do not have any neighbor in common ($N(u) \cap N(v) = \emptyset$) then it is obvious that no decision made by node u will affect node v and vice versa. Therefore, nodes u and v can enter into their critical section simultaneously. Let $G = (V; E)$ the graph induced by the network topology; where V and E respectively denote the set of nodes and the set of links. Formally, $\forall u, v \in V, (v \notin N(u) \wedge u \notin N(v)) \Rightarrow ((state(u) = state(v)) \vee (state(u) \neq state(v)))$. ■

Theorem 3. *CGSCP provides a local mutual exclusion for the sensing unit sleep scheduling problem.*

Proof: CGSCP allows a safe sensing unit scheduling and a weak fairness. Proof is given by Lemma 1 and 2. CGSCP allows a mutual exclusion; Lemma 3 showed that this process is fully localized. ■

Corollary 1. *In the absence of fault, CGSCP does not create any coverage hole.*

TABLE I. SIMULATION PARAMETERS

Parameter	Value
Deployment area	500 m X 500 m
Number of sensors	100 to 1000
Sensors' initial energy (Ei)	0,2 J
Self-discharge per second	0,1 μJ
Energy threshold ($Ethr$)	100 μJ
E_{elec}	50 nJ/bit
e_{fs}	10 nJ/bit/m^2
e_{amp}	0,0013 nJ/bit/m^4
d_0	87 m
Message length (l)	2000 bits
U_{sup}	2,7 V
I_{sens}	25 mA
t_{sens}	0,25 ms
Data length (b)	200 bits
$nitrmax$	100 to 200

TABLE II. ENERGY LOST DURING STATE TRANSITION

	Active	Sleep
Active	-	0.4mW
Sleep	0.4mW	-

TABLE III. STATE TRANSITION DELAYS

	Active	Sleep
Active	-	2μs
Sleep	2μs	-

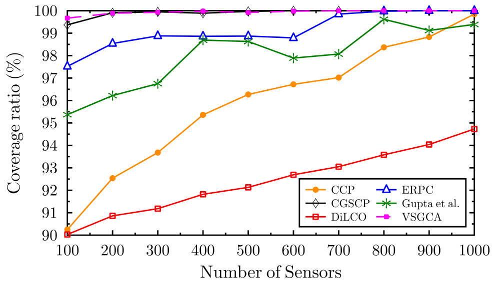
For simulation campaigns, we used the radio energy consumption model by Heinzelman *et al.* [45] and a sensing unit energy consumption model by Halgamuge *et al.* [46].

Tables I to III summarize parameters we used for the simulation campaigns we conducted with respect to three metrics, namely, k-coverage efficiency, energy efficiency and network lifetime. Each experiment was repeated 10 times as nodes population was increased.

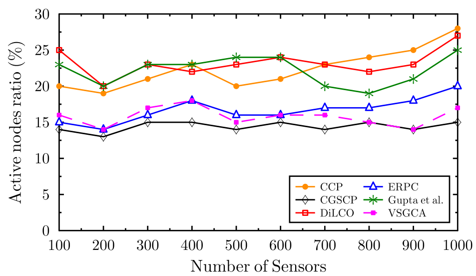
V. RESULTS AND DISCUSSION

A. k-Coverage Efficiency

Fig. 3a shows that among the 6 evaluated protocols, only CGSCP and VSGCA help to preserve virtually 100% of the coverage ratio in the case of 1-coverage despite the increase in the number of sensor-nodes. However, as shown in Fig. 3b, CGSCP requires to keep active on average about 15% of the deployed nodes. This trend continues in the case of 4-coverage as depicted in Fig. 3c and Fig. 3d. The number of nodes kept active logically increases according to parameter k. However, CGSCP is the protocol that keeps the least number of active nodes. These performances are due to the detection process. Indeed, the strategy we used has a good accuracy and precision ratio even for heterogeneous networks [16]. DiLCO and the solution by Gupta *et al.* are the worst performing protocols since they are essentially based on the scheduling process with a less precise random redundancy detection process. Therefore, one can conclude that deterministic strategies provide the best k-coverage ratio.



(a)



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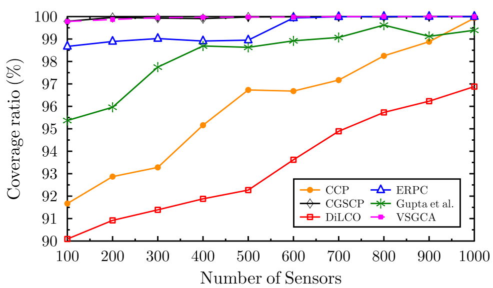
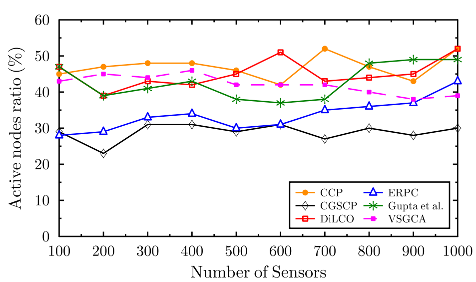


(c)



(d)

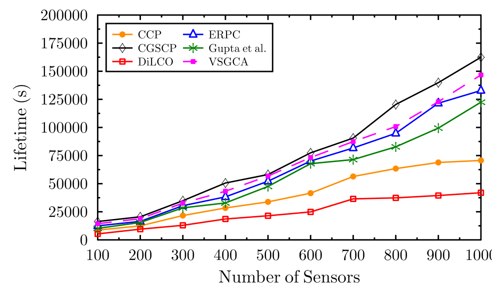
Fig. 3. k-coverage efficiency vs. Number of sensors. (a) coverage ratio for k = 1, (b) active nodes ratio for k = 1, (c) coverage ratio for k = 4, (d) active nodes ratio for k = 4.

B. Network Lifetime and Energy Efficiency

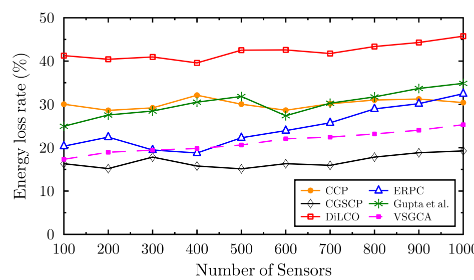
Fig. 4a shows that CGSCP is the protocol that best increases network lifetime i.e. that keeps the longest the coverage ratio above 98%. Fig. 4b shows that this performance requires to spend on average 17% of the initial energy in spite of the increasing of the number of sensor-nodes. This trend continues as parameter k increases. Logically, network lifetime decreases as parameter k grows; since the number of nodes to be kept active depends on parameter k.

CCP and DiLCO are the two protocols of which performances are the lowest. This situation is due to the poor performances of their redundancy detection process.

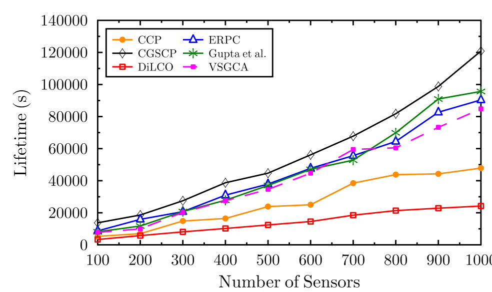
As for CGSCP, these results show the energy-efficiency of the local mutual exclusion strategy. Indeed, it prevents nodes that are in Frozen state to unnecessarily rediscover their neighborhood. Furthermore, this strategy allows load balancing since it guarantees to each node the opportunity of entering into Sleep state.



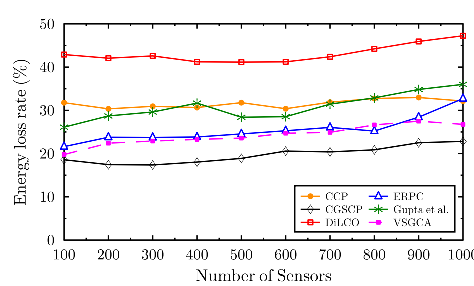
(a)



(b)



(c)



(d)

Fig. 4. Network lifetime & Energy Efficiency with a 98% coverage ratio. (a) Network lifetime for k = 1, (b) Energy Efficiency for k = 1, (c) Network lifetime for k = 4, (d) Energy Efficiency for k = 4.

VI. Conclusion

In this paper, we investigated the problem of area k-coverage in a heterogeneous wireless sensor network. We assumed that the underlying application requires that every points in the Field of Interest (FoI) be covered by at least $k(k \geq 1)$ sensor-nodes. We proposed an asynchronous and localized protocol referred to as CGSCP (Coverage Greedy Scheduling Coordination Protocol). The latter use a crossing points-based technique and a local mutual exclusion-based heuristic to, respectively, detect redundant nodes and schedule their duty-cycles. Several simulations have been carried out to evaluate the proposed protocol. Results show that our scheme provides a lower coverage ratio and is more energy-efficient than some recently proposed solutions.

In a future work, we plan to extend our protocol by adding a process that helps to explicitly tolerate both node and link failures. Finally, it would be also interesting to implement the CGSCP protocol in 3D more realistic environment.

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A Novel Hybrid Quicksort Algorithm Vectorized using AVX-512 on Intel Skylake

Berenger Bramas
Max Planck Computing and Data Facility (MPCDF)
Gieenbachstrae 2
85748 Garching, Germany

***Abstract*—The modern CPU's design, which is composed of hierarchical memory and SIMD/vectorization capability, governs the potential for algorithms to be transformed into efficient implementations. The release of the AVX-512 changed things radically, and motivated us to search for an efficient sorting algorithm that can take advantage of it. In this paper, we describe the best strategy we have found, which is a novel two parts hybrid sort, based on the well-known Quicksort algorithm. The central partitioning operation is performed by a new algorithm, and small partitions/arrays are sorted using a branch-free Bitonic-based sort. This study is also an illustration of how classical algorithms can be adapted and enhanced by the AVX-512 extension. We evaluate the performance of our approach on a modern Intel Xeon Skylake and assess the different layers of our implementation by sorting/partitioning integers, double floating-point numbers, and key/value pairs of integers. Our results demonstrate that our approach is faster than two libraries of reference: the GNU *C++* sort algorithm by a speedup factor of 4, and the Intel IPP library by a speedup factor of 1.4.**

Keywords*—*Quicksort; Bitonic; sort; vectorization; SIMD; AVX-512; Skylake

I. Introduction

Sorting is a fundamental problem in computer science that always had the attention of the research community, because it is widely used to reduce the complexity of some algorithms. Moreover, sorting is a central operation in specific applications such as, but not limited to, database servers [1] and image rendering engines [2]. Therefore, having efficient sorting libraries on new architecture could potentially leverage the performance of a wide range of applications.

The vectorization — that is, the CPU's capability to apply a single instruction on multiple data (SIMD) — improves continuously, one CPU generation after the other. While the difference between a scalar code and its vectorized equivalent was *"only"* of a factor of 4 in the year 2000 (SSE), the difference is now up to a factor of 16 (AVX-512). Therefore, it is indispensable to *vectorize* a code to achieve high-performance on modern CPUs, by using dedicated instructions and registers. The conversion of a scalar code into a vectorized equivalent is straightforward for many classes of algorithms and computational kernels, and it can even be done with auto-vectorization for some of them. However, the opportunity of vectorization is tied to the memory/data access patterns, such that data-processing algorithms (like sorting) usually require an important effort to be transformed. In addition, creating a fully vectorized implementation, without any scalar sections, is only possible and efficient if the instruction set provides the needed operations. Consequently, new instruction sets, such as the AVX-512, allow for the use of approaches that were not feasible previously.

The Intel Xeon Skylake (SKL) processor is the second CPU that supports AVX-512, after the Intel Knight Landing. The SKL supports the AVX-512 instruction set [13]: it supports Intel AVX-512 foundational instructions (AVX-512F), Intel AVX-512 conflict detection instructions (AVX-512CD), Intel AVX-512 byte and word instructions (AVX-512BW), Intel AVX-512 doubleword and quadword instructions (AVX-512DQ), and Intel AVX-512 vector length extensions instructions (AVX-512VL). The AVX-512 not only allows work on SIMD-vectors of double the size, compared to the previous AVX(2) set, it also provides various new operations.

Therefore, in the current paper, we focus on the development of new sorting strategies and their efficient implementation for the Intel Skylake using AVX-512. The contributions of this study are the following:

- proposing a new partitioning algorithm using AVX-512,
- defining a new Bitonic-sort variant for small arrays using AVX-512,
- implementing a new Quicksort variant using AVX-512.

All in all, we show how we can obtain a fast and vectorized sorting algorithm[1].

The rest of the paper is organized as follows: Section II gives background information related to vectorization and sorting. We then describe our approach in Section III, introducing our strategy for sorting small arrays, and the vectorized partitioning function, which are combined in our Quicksort variant. Finally, we provide performance details in Section IV and the conclusion in Section V.

II. Background

A. Sorting Algorithms

1) Quicksort (QS) Overview: QS was originally proposed in [3]. It uses a *divide-and-conquer* strategy, by recursively

[1]The functions described in the current study are available at https://gitlab.mpcdf.mpg.de/bbramas/avx-512-sort. This repository includes a clean header-only library (branch master) and a test file that generates the performance study of the current manuscript (branch paper). The code is under MIT license.

partitioning the input array, until it ends with partitions of one value. The partitioning puts values lower than a *pivot* at the beginning of the array, and greater values at the end, with a linear complexity. QS has a worst-case complexity of O(n^2), but an average complexity of O(n log n) in practice. The complexity is tied to the choice of the partitioning pivot, which must be close to the median to ensure a low complexity. However, its simplicity in terms of implementation, and its speed in practice, has turned it into a very popular sorting algorithm. Fig. 1 shows an example of a QS execution.

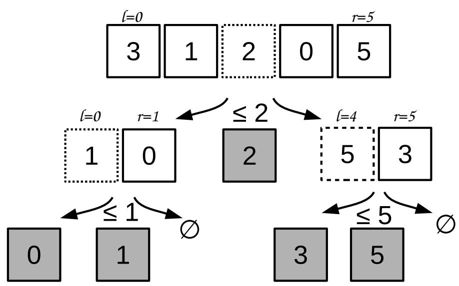
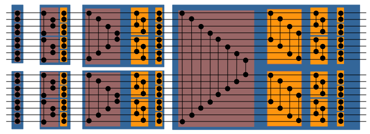


Fig. 1: Quicksort example to sort $[3, 1, 2, 0, 5]$ to $[0, 1, 2, 3, 5]$. The pivot is equal to the value in the middle: the first pivot is 2, then at second recursion level it is 1 and 5.

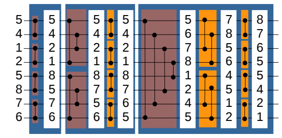
We provide in Appendix A the scalar QS algorithm. Here, the term *scalar* refers to a single value at the opposite of an SIMD vector. In this implementation, the choice of the pivot is naively made by selecting the value in the middle before partitioning, and this can result in very unbalanced partitions. This is why more advanced heuristics have been proposed in the past, like selecting the median from several values, for example.

2) GNU std::sort Implementation (STL): The worst case complexity of QS makes it no longer suitable to be used as a standard *C++* sort. In fact, a complexity of O(n log n) in average was required until year 2003 [4], but it is now a worst case limit [5] that a pure QS implementation cannot guarantee. Consequently, the current implementation is a 3-part hybrid sorting algorithm *i.e.* it relies on 3 different algorithms[2]. The algorithm uses an Introsort [6] to a maximum depth of $2 \times \log^2 n$ to obtain small partitions that are then sorted using an insertion sort. Introsort is itself a 2-part hybrid of Quicksort and heap sort.

3) Bitonic Sorting Network: In computer science, a sorting network is an abstract description of how to sort a fixed number of values *i.e.* how the values are compared and exchanged. This can be represented graphically, by having each input value as a horizontal line, and each *compare and exchange* unit as a vertical connection between those lines. There are various examples of sorting networks in the literature, but we concentrate our description on the Bitonic sort from [7]. This network is easy to implement and has an algorithm complexity of O(n log(n)^2). It has demonstrated good performances on parallel computers [8] and GPUs [9]. Fig. 2a shows a Bitonic sorting network to process 16 values. A sorting network can



(a) Bitonic sorting network for input of size 16. All vertical bars/switches exchange values in the same direction.



(b) Example of 8 values sorted by a Bitonic sorting network.

Fig. 2: Bitonic sorting network examples. In red boxes, the exchanges are done from extremities to the center. Whereas in orange boxes, the exchanges are done with a linear progression.

be seen as a time line, where input values are transferred from left to right, and exchanged if needed at each vertical bar. We illustrate an execution in Fig. 2b, where we print the intermediate steps while sorting an array of 8 values. The Bitonic sort is not stable because it does not maintain the original order of the values.

If the size of the array to sort is known, it is possible to implement a sorting network by hard-coding the connections between the lines. This can be seen as a direct mapping of the picture. However, when the array size is unknown, the implementation can be made more flexible by using a formula/rule to decide when to compare/exchange values.

B. Vectorization

The term vectorization refers to a CPU's feature to apply a single operation/instruction to a vector of values instead of only a single value [10]. It is common to refer to this concept by Flynn's taxonomy term, SIMD, for single instruction on multiple data. By adding SIMD instructions/registers to CPUs, it has been possible to increase the peak performance of single cores, despite the stagnation of the clock frequency. The same strategy is used on new hardware, where the length of the SIMD registers has continued to increase. In the rest of the paper, we use the term *vector* for the data type managed by the CPU in this sense. It has no relation to an expandable vector data structure, such as *std::vector*. The size of the vectors is variable and depends on both the instruction set and the type of vector element, and corresponds to the size of the registers in the chip. Vector extensions to the *x86* instruction set, for example, are SSE [11], AVX [12], and AVX512 [13], which support vectors of size 128, 256 and 512 bits, respectively. This means that an SSE vector is able to store four single precision floating point numbers or two double precision values. Fig. 3 illustrates the difference between a scalar summation and a vector summation for SSE or AVX, respectively. An AVX-512 SIMD-vector is able to store 8 double precision floating-point numbers or 16 integer values, for example. Throughout this document, we use *intrinsic* function extension instead of the assembly language to write vectorized code on top of the AVX-512 instruction set. Intrinsics are small functions that are intended to be replaced with a single assembly instruction by the compiler.

1) AVX-512 Instruction Set: As previous *x86* vectorization extensions, the AVX-512 has instructions to load a contiguous block of values from the main memory and to transform it

[2]See the libstdc++ documentation on the sorting algorithm available at https://gcc.gnu.org/onlinedocs/libstdc++/libstdc++-html-USERS-4.4/a01347.html#l05207

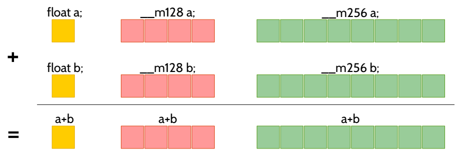


Fig. 3: Summation example of single precision floating-point values using: (■) scalar standard *C++* code, (■) SSE SIMD-vector of 4 values, (■) AVX SIMD-vector of 8 values.

into a SIMD-vector (load). It is also possible to fill a SIMD-vector with a given value (set), and move back a SIMD-vector into memory (store). A permutation instruction allows to re-order the values inside a SIMD-vector using a second integer array which contains the permutation indexes. This operation was possible in since AVX/AVX2 using *permutevar8x32* (instruction vperm(d,ps)). The instructions *vminpd/vpminsd* return a SIMD-vector where each value correspond to the minimum of the values from the two input vectors at the same position. It is possible to obtain the maximum with instructions *vpmaxsd/vmaxpd*.

In AVX-512, the value returned by a test/comparison (*vpcmpd/vcmppd*) is a mask (integer) and not an SIMD-vector of integers, as it was in SSE/AVX. Therefore, it is easy to modify and work directly on the mask with arithmetic and binary operations for scalar integers. Among the mask-based instructions, the *mask move (vmovdqa32/vmovapd)* allows for the selection of values between two vectors, using a mask. Achieving the same result was possible in previous instruction sets using the *blend* instruction since SSE4, and using several operations with previous instruction sets.

The AVX-512 provides operations that do not have an equivalent in previous extensions of the *x86* instruction sets, such as the *store-some* (*vpcompressps/vcompresspd*) and *load-some* (*vmovups/vmovupd*). The *store-some* operation allows to save only a part of a SIMD-vector into memory. Similarly, the *load-some* allows to load less values than the size of a SIMD-vector from the memory. The values are loaded/saved contiguously. This is a major improvement, because without this instruction, several operations are needed to obtain the same result. For example, to save some values from a SIMD-vector *v* at address *p* in memory, one possibility is to load the current values from *p* into a SIMD-vector *v'*, permute the values in *v* to move the values to store at the beginning, merge *v* and *v'*, and finally save the resulting vector.

C. Related Work on Vectorized Sorting Algorithms

The literature on sorting and vectorized sorting implementations is extremely large. Therefore, we only cite some of the studies that we consider most related to our work.

The sorting technique from [14] tries to remove branches and improves the prediction of a scalar sort, and they show a speedup by a factor of 2 against the STL (the implementation of the STL was different at that time). This study illustrates the early strategy to adapt sorting algorithms to a given hardware, and also shows the need for low-level optimizations, due to the limited instructions available at that time.

In [15], the authors propose a parallel sorting on top of combosort vectorized with the VMX instruction set of IBM architecture. Unaligned memory access is avoided, and the L2 cache is efficiently managed by using an out-of-core/blocking scheme. The authors show a speedup by a factor of 3 against the GNU *C++* STL.

In [16], the authors use a sorting-network for small-sized arrays, similar to our own approach. However, instead of dividing the main array into sorted partitions (partitions of increasing contents), and applying a small efficient sort on each of those partitions, the authors perform the opposite. They apply multiple small sorts on sub-parts of the array, and then they finish with a complicated merge scheme using extra memory to globally sort all the sub-parts. A very similar approach was later proposed in [17].

The recent work in [18] targets AVX2. The authors use a Quicksort variant with a vectorized partitioning function, and an insertion sort once the partitions are small enough (as the STL does). The partition method relies on look-up tables, with a mapping between the comparison's result of an SIMD-vector against the pivot, and the move/permutation that must be applied to the vector. The authors demonstrate a speedup by a factor of 4 against the STL, but their approach is not always faster than the Intel IPP library. The proposed method is not suitable for AVX-512 because the lookup tables will occupy too much memory. This issue, as well as the use of extra memory, can be solved with the new instructions of the AVX-512. As a side remark, the authors do not compare their proposal to the standard *C++ partition* function, even so, it is the only part of their algorithm that is vectorized.

III. Sorting with AVX-512

A. Bitonic-Based Sort on AVX-512 SIMD-Vectors

In this section, we describe our method to sort small arrays that contain less than 16 times *VEC_SIZE*, where *VEC_SIZE* is the number of values in a SIMD-vector. This function is later used in our final QS implementation to sort small enough partitions.

1) Sorting one SIMD-vector: To sort a single vector, we perform the same operations as the ones shown in Fig. 2a: we compare and exchange values following the indexes from the Bitonic sorting network. However, thanks to the vectorization, we are able to work on the entire vector without having to iterate on the values individually. We know the positions that we have to compare and exchange at the different stages of the algorithm. This is why, in our approach, we rely on static (hard-coded) permutation vectors, as shown in Algorithm 1. In this algorithm, the *compare_and_exchange* function performs all the *compare and exchange* that are applied at the same time in the Bitonic algorithm *i.e.* the operations that are at the same horizontal position in the figure. To have a fully vectorized function, we implement the *compare_and_exchange* in three steps. First, we permute the input vector *v* into *v'* with the given permutation indexes *p*. Second, we obtain two vectors w_{min} and w_{max} that contain the minimum and maximum values between both *v* and *v'*. Finally, we selects the values from w_{min} and w_{max} with a mask-based move, where the mask indicates in which direction the exchanges have to be done. The *C++* source code of a fully vectorized branch-free implementation is given in Appendix B (Code 1).

Algorithm 1: SIMD Bitonic sort for one vector of double floating-point values.

```
Input: vec: a double floating-point AVX-512 vector to sort.
Output: vec: the vector sorted.
function simd_bitonic_sort_1v(vec)
    compare_and_exchange(vec, [6, 7, 4, 5, 2, 3, 0, 1])
    compare_and_exchange(vec, [4, 5, 6, 7, 0, 1, 2, 3])
    compare_and_exchange(vec, [6, 7, 4, 5, 2, 3, 0, 1])
    compare_and_exchange(vec, [0, 1, 2, 3, 4, 5, 6, 7])
    compare_and_exchange(vec, [5, 4, 7, 6, 1, 0, 3, 2])
    compare_and_exchange(vec, [6, 7, 4, 5, 2, 3, 0, 1])
```

2) Sorting more than one SIMD-vectors: The principle of using static permutation vectors to sort a single SIMD-vector can be applied to sort several SIMD-vectors. In addition, we can take advantage of the repetitive pattern of the Bitonic sorting network to re-use existing functions. More precisely, to sort V vectors, we re-use the function to sort $V/2$ vectors and so on. We provide an example to sort two SIMD-vectors in Algorithm 2, where we start by sorting each SIMD-vector individually using the *bitonic_simd_sort_1v* function. Then, we compare and exchange values between both vectors (line 5), and finally applied the same operations on each vector individually (lines 6 to 11). In our sorting implementation, we provide the functions to sort up to 16 SIMD-vectors, which correspond to 256 integer values or 128 double floating-point values.

Algorithm 2: SIMD bitonic sort for two vectors of double floating-point values.

```
   Input: vec1 and vec2: two double floating-point AVX-512 vectors to sort.
   Output: vec1 and vec2: the two vectors sorted with vec1 lower or equal
           than vec2.
1  function simd_bitonic_sort_2v(vec1, vec2)
2      // Sort each vector using bitonic_simd_sort_1v
3      simd_bitonic_sort_1v(vec1)
4      simd_bitonic_sort_1v(vec2)
5      compare_and_exchange_2v(vec1, vec2, [0, 1, 2, 3, 4, 5, 6, 7])
6      compare_and_exchange(vec1, [3, 2, 1, 0, 7, 6, 5, 4])
7      compare_and_exchange(vec2, [3, 2, 1, 0, 7, 6, 5, 4])
8      compare_and_exchange(vec1, [5, 4, 7, 6, 1, 0, 3, 2])
9      compare_and_exchange(vec2, [5, 4, 7, 6, 1, 0, 3, 2])
10     compare_and_exchange(vec1, [6, 7, 4, 5, 2, 3, 0, 1])
11     compare_and_exchange(vec2, [6, 7, 4, 5, 2, 3, 0, 1])
```

3) Sorting small arrays: Each of our SIMD-Bitonic-sort functions are designed for a specific number of SIMD-vectors. However, we intend to sort arrays that do not have a size multiple of the SIMD-vector's length, because they are obtained from the partitioning stage of the QS. Consequently, when we have to sort a small array, we first load it into SIMD-vectors, and then, we pad the last vector with the greatest possible value. This guarantee that the padding values have no impact on the sorting results by staying at the end of the last vector. The selection of appropriate SIMD-Bitonic-sort function, that matches the size of the array to sort, can be done efficiently with a switch statement. In the following, we refer to this interface as the *simd_bitonic_sort_wrapper* function.

B. Partitioning with AVX-512

Algorithm 3 shows our strategy to develop a vectorized partitioning method. This algorithm is similar to a scalar partitioning function: there are iterators that start from both extremities of the array to keep track of where to load/store the values, and the process stops when some of these iterators meet. In its steady state, the algorithm loads an SIMD-vector using the left or right indexes (at lines 19 and 24), and partitions it using the *partition_vec* function (at line 27). The *partition_vec* function compares the input vector to the pivot vector (at line 47), and stores the values — lower or greater — directly in the array using a store-some instruction (at lines 51 and 55). The store-some is an AVX-512 instruction that we described in Section II-B1. The initialization of our algorithm starts by loading one vector from each array's extremities to ensure that no values will be overwritten during the steady state (lines 12 and 16). This way, our implementation works in-place and only needs three SIMD-vectors. Algorithm 3 also includes, as side comments, possible optimizations in case the array is more likely to be already partitioned (A), or to reduce the data displacement of the values (B). The AVX-512 implementation of this algorithm is given in Appendix B (Code 2). One should note that we use a scalar partition function if there are less than 2 × VEC_SIZE values in the given array (line 3).

C. Quicksort Variant

Our QS is given in Algorithm 4, where we partition the data using the *simd_partition* function from Section III-B, and then sort the small partitions using the *simd_bitonic _sort_wrapper* function from Section III-A. The obtained algorithm is very similar to the scalar QS given in Appendix A.

D. Sorting Key/Value Pairs

The previous sorting methods are designed to sort an array of numbers. However, some applications need to sort key/value pairs. More precisely, the sort is applied on the keys, and the values contain extra information and could be pointers to arbitrary data structures, for example. Storing each key/value pair contiguously in memory is not adequate for vectorization because it requires transforming the data. Therefore, in our approach, we store the keys and the values in two distinct arrays. To extend the SIMD-Bitonic-sort and SIMD-partition functions, we must ensure that the same permutations/moves are applied to the keys and the values. For the partition function, this is trivial. The same mask is used in combination with the store-some instruction for both arrays. For the Bitonic-based sort, we manually apply the permutations that were done on the vector of keys to the vector of values. To do so, we first save the vector of keys *k* before it is permuted by a *compare and exchange*, using the Bitonic permutation vector of indexes *p*, into *k'*. We compare *k* and *k'* to obtain a mask *m* that expresses what moves have been done. Then, we permute our vector of values *v* using *p* into *v'*, and we select the correct values between *v* and *v'* using *m*. Consequently, we perform this operation at the end of the *compare_and_exchange* in all the Bitonic-based sorts.

IV. Performance Study

A. Configuration

We asses our method on an Intel(R) Xeon(R) Platinum 8170 *Skylake* CPU at 2.10GHz, with caches of sizes 32K-Bytes, 1024K-Bytes and 36608K-Bytes, at levels L1, L2 and L3, respectively. The process and allocations are bound with *numactl –physcpubind=0 –localalloc*. We use the Intel

Algorithm 3: SIMD partitioning. VEC_SIZE is the number of values inside a SIMD-vector of type array's elements.

```
Input: array: an array to partition. length: the size of array. pivot: the
    reference value
Output: array: the array partitioned. left_w: the index between the
    values lower and larger than the pivot.
function simd_partition(array, length, pivot)
    // If too small use scalar partitioning
    if length ≤ 2 × VEC_SIZE then
        Scalar_partition(array, length)
        return
    end
    // Set: Fill a vector with all values equal to pivot
    pivotvec = simd_set_from_one(pivot)
    // Init iterators and save one vector on each extremity
    left = 0
    left_w = 0
    left_vec = simd_load(array, left)
    left = left + VEC_SIZE
    right = length-VEC_SIZE
    right_w = length
    right_vec = simd_load(array, right)
    while left + VEC_SIZE ≤ right do
        if (left - left_w) ≤ (right_w - right) then
            val = simd_load(array, left)
            left = left + VEC_SIZE
            // (B) Possible optimization, swap val and left_vec
        else
            right = right - VEC_SIZE
            val = simd_load(array, right)
            // (B) Possible optimization, swap val and right_vec
        end
        [left_w, right_w] = partition_vec(array, val, pivotvec, left_w,
          right_w)
    end
    // Process left_val and right_val
    [left_w, right_w] = partition_vec(array, left_val, pivotvec, left_w,
      right_w)
    [left_w, right_w] = partition_vec(array, right_val, pivotvec, left_w,
      right_w)
    // Proceed remaining values (less than VEC_SIZE values)
    nb_remaining = right - left
    val = simd_load(array, left)
    left = right
    mask = get_mask_less_equal(val, pivotvec)
    mask_low = cut_mask(mask, nb_remaining)
    mask_high = cut_mask(reverse_mask(mask) , nb_remaining)
    // (A) Possible optimization, do only if mask_low is not 0
    simd_store_some(array, left_w, mask_low, val)
    left_w = left_w + mask_nb_true(mask_low)
    // (A) Possible optimization, do only if mask_high is not 0
    right_w = right_w - mask_nb_true(mask_high)
    simd_store_some(array, right_w, mask_high, val)
    return left_w
function partition_vec(array, val, pivotvec, left_w, right_w)
    mask = get_mask_less_equal(val, pivotvec)
    nb_low = mask_nb_true(mask)
    nb_high = VEC_SIZE-nb_low
    // (A) Possible optimization, do only if mask is not 0
    simd_store_some(array, left_w, mask, val)
    left_w = left_w + nb_low
    // (A) Possible optimization, do only if mask is not all true
    right_w = right_w - nb_high
    simd_store_some(array, right_w, reverse_mask(mask), val)
    return [left_w, right_w]
```

compiler 17.0.2 (20170213) with aggressive optimization flag *-O3*.

We compare our implementation against two references. The first one is the GNU STL 3.4.21 from which we use the *std::sort* and *std::partition* functions. The second one is the Intel Integrated Performance Primitives (IPP) 2017 which is a library optimized for Intel processors. We use the IPP radix-based sort (function *ippsSortRadixAscend_[type]_I*). This function require additional space, but it is known as one

Algorithm 4: SIMD Quicksort. $select\_pivot\_pos$ returns a pivot.

```
Input: array: an array to sort. length: the size of array.
Output: array: the array sorted.
function simd_QS(array, length)
    simd_QS_core(array, 0, length-1)
function simd_QS_core(array, left, right)
    // Test if we must partition again or if we can sort
    if left + SORT_BOUND < right then
        pivot_idx = select_pivot_pos(array, left, right)
        swap(array[pivot_idx], array[right])
        partition_bound = simd_partition(array, left, right,
          array[right])
        swap(array[partition_bound], array[right])
        simd_QS_core(array, left, partition_bound-1)
        simd_QS_core(array, partition_bound+1, right)
    else
        simd_bitonic_sort_wrapper(sub_array(array, left),
          right-left+1)
    end
```

of the fastest existing sorting implementation.

The test file used for the following benchmark is available online[3], it includes the different sorts presented in this study plus some additional strategies and tests. Our SIMD-QS uses a 3-values median pivot selection (similar to the STL sort function). The arrays to sort are populated with randomly generated values.

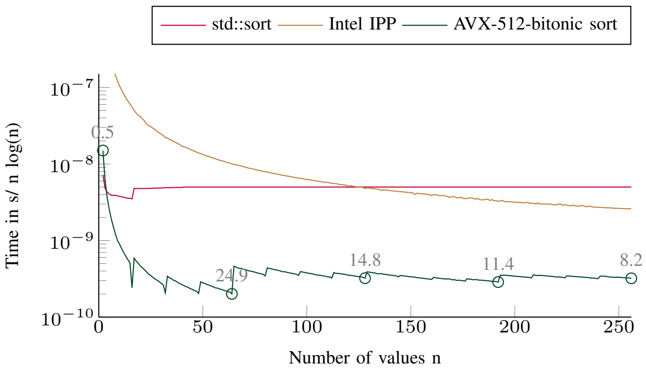
B. Performance to Sort Small Arrays

Fig. 4 shows the execution times to sort arrays of size from 1 to 16 × *VEC_SIZE*, which corresponds to 128 double floating-point values, or 256 integer values. We also test arrays of size not multiple of the SIMD-vector's length. The AVX-512-bitonic always delivers better performance than the Intel IPP for any size, and better performance than the STL when sorting more than 5 values. The speedup is significant, and is around 8 in average. The execution time per item increases every *VEC_SIZE* values because the cost of sorting is not tied to the number of values but to the number of SIMD-vectors to sort, as explained in Section III-A3. For example, in Fig. 4a, the execution time to sort 31 or 32 values is the same, because we sort one SIMD-vector of 32 values in both cases. Our method to sort key/value pairs seems efficient, see Fig. 4c, because the speedup is even better against the STL compared to the sorting of integers.

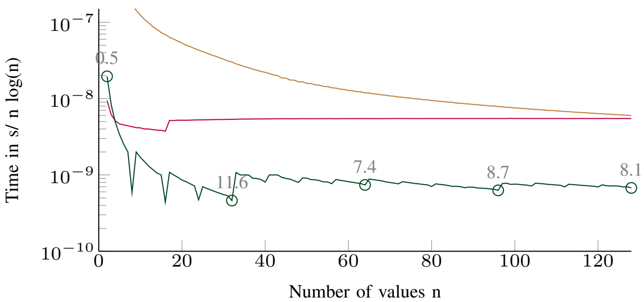
C. Partitioning Performance

Fig. 5 shows the execution times to partition using our AVX-512-partition or the STL's partition function. Our method provides again a speedup of an average factor of 4. For the three configurations, an overhead impacts our implementation and the STL when partitioning arrays larger than 10^7 items. Our AVX-512-partition remains faster, but its speedup decreases from 4 to 3. This phenomena is related to cache effects since 10^7 integers values occupy 40M-Bytes, which is more than the L3 cache size. In addition, we see that this effect starts from 10^5 when partitioning key/value pairs.

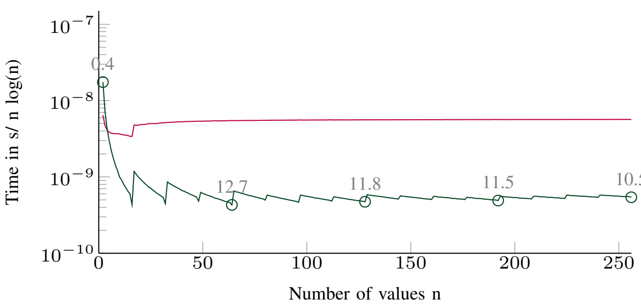
[3]The test file that generates the performance study is available at https://gitlab.mpcdf.mpg.de/bbramas/avx-512-sort (branch paper) under MIT license.



(a) Integer (int).

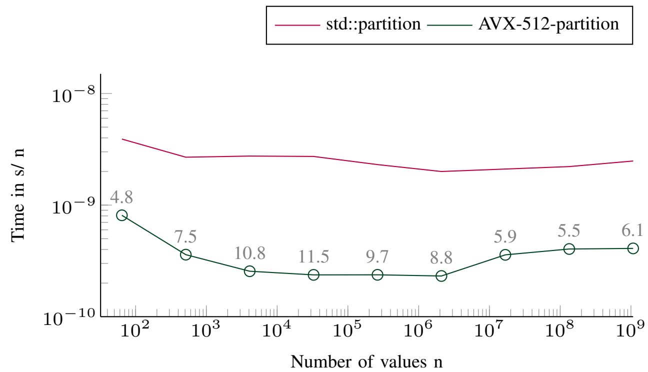


(b) Floating-point (double)

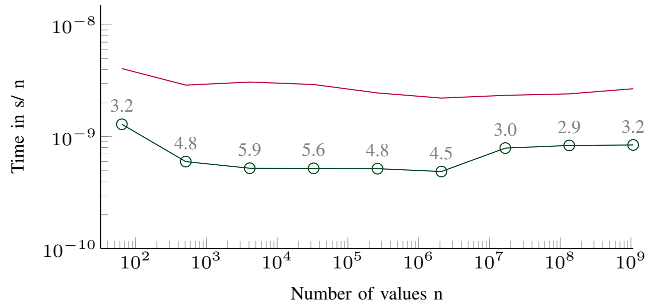


(c) Key/value integer pair (int[2]).

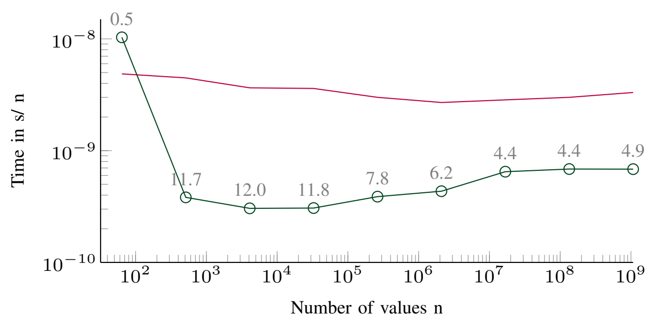
Fig. 4: Execution time divided by *n log(n)* to sort from 1 to 16 × *VEC_SIZE* values. The execution time is obtained from the average of 10^4 sorts for each size. The speedup of the AVX-512-bitonic against the fastest between STL and IPP is shown above the AVX-512-bitonic line.



(a) Integer (int).



(b) Floating-point (double)

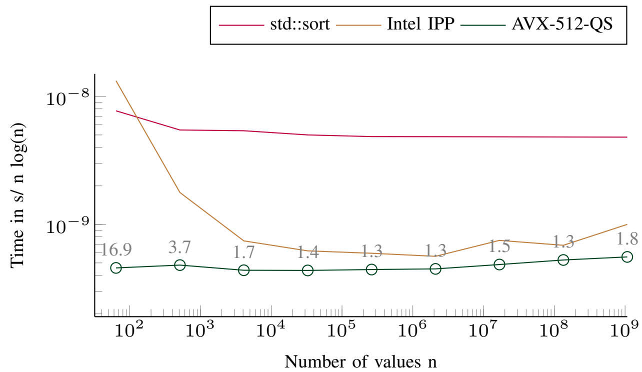


(c) Key/value integer pair (int[2]).

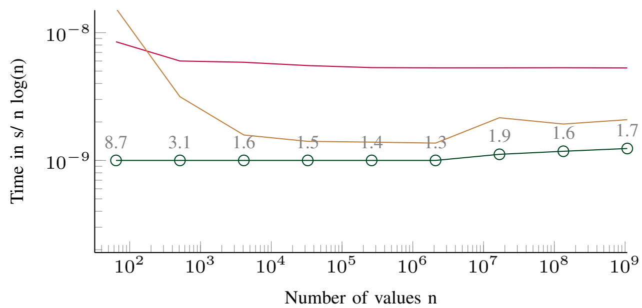
Fig. 5: Execution time divided by *n* of elements to partition arrays filled with random values with sizes from 2^1 to 2^{30} ($\approx 10^9$).The pivot is selected randomly. the AVX-512-partition line. The execution time is obtained from the average of 20 executions. The speedup of the AVX-512-partition against the STL is shown above.

D. Performance to Sort Large Arrays

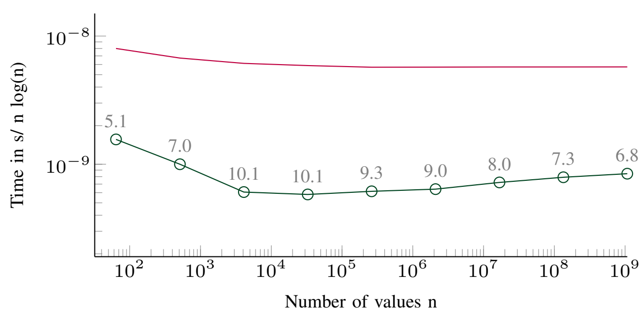
Fig. 6 shows the execution times to sort arrays up to a size of 10^9 items. Our AVX-512-QS is always faster in all configurations. The difference between AVX-512-QS and the STL sort seems stable for any size with a speedup of more than 6 to our benefit. However, while the Intel IPP is not efficient for arrays with less than 10^4 elements, its performance is really close to the AVX-512-QS for large arrays. The same effect found when partitioning appears when sorting arrays larger than 10^7 items. All three sorting functions are impacted, but the IPP seems more slowdown than our method, because it is based on a different access pattern, such that the AVX-512-QS is almost twice as fast as IPP for a size of 10^9 items.



(a) Integer (int)



(b) Floating-point (double)



(c) Key/value integer pair (int[2])

Fig. 6: Execution time divided by *n log(n)* to sort arrays filled with random values with sizes from 2^1 to 2^{30} ($\approx 10^9$). The execution time is obtained from the average of 5 executions. The speedup of the AVX-512-bitonic against the fastest between STL and IPP is shown above the AVX-512-bitonic line.

V. Conclusions

In this paper, we introduced new Bitonic sort and a new partition algorithm that have been designed for the AVX-512 instruction set. These two functions are used in our Quicksort variant which makes it possible to have a fully vectorized implementation (at the exception of partitioning tiny arrays). Our approach shows superior performance on Intel SKL in all configurations against two reference libraries: the GNU *C++* STL, and the Intel IPP. It provides a speedup of 8 to sort small arrays (less than 16 SIMD-vectors), and a speedup of 4 and 1.4 for large arrays, against the *C++* STL and the Intel IPP, respectively. These results should also motivate the community to revisit common problems, because some algorithms may become competitive by being vectorizable, or improved, thanks to AVX-512's novelties. Our source code is publicly available and ready to be used and compared. In the future, we intend to design a parallel implementation of our AVX-512-QS, and we expect the recursive partitioning to be naturally parallelized with a task-based scheme on top of OpenMP.

Appendix

A. Scalar Quicksort Algorithm

Algorithm 5: Quicksort

```
Input: array: an array to sort. length: the size of array.
Output: array: the array sorted.
function QS(array, length)
    QS_core(array, 0, length-1)

function QS_core(array, left, right)
    if left < right then
        // Naive method, select value in the middle
        pivot_idx = ((right-left)/2) + left
        swap(array[pivot_idx], array[right])
        partition_bound = partition(array, left, right, array[right])
        swap(array[partition_bound], array[right])
        QS_core(array, left, partition_bound-1)
        QS_core(array, partition_bound+1, right)
    end

function partition(array, left, right, pivot_value)
    for idx_read ← left to right do
        if array[idx_read] ¡ pivot_value then
            swap(array[idx_read], array[left])
            left += 1
        end
    end
    return left;
```

B. Source Code Extracts

```
inline __m512d AVX_512_bitonic_sort_1v(__m512d input){
{
    __m512i idxNoNeigh = _mm512_set_epi64(6, 7, 4, 5, 2, 3, 0, 1);
    __m512d permNeigh = _mm512_permutexvar_pd(idxNoNeigh, input);
    __m512d permNeighMin = _mm512_min_pd(permNeigh, input);
    __m512d permNeighMax = _mm512_max_pd(permNeigh, input);
    input = _mm512_mask_mov_pd(permNeighMin, 0xAA, permNeighMax);
}
{
    __m512i idxNoNeigh = _mm512_set_epi64(4, 5, 6, 7, 0, 1, 2, 3);
    __m512d permNeigh = _mm512_permutexvar_pd(idxNoNeigh, input);
    __m512d permNeighMin = _mm512_min_pd(permNeigh, input);
    __m512d permNeighMax = _mm512_max_pd(permNeigh, input);
    input = _mm512_mask_mov_pd(permNeighMin, 0xCC, permNeighMax);
}
{
    __m512i idxNoNeigh = _mm512_set_epi64(6, 7, 4, 5, 2, 3, 0, 1);
    __m512d permNeigh = _mm512_permutexvar_pd(idxNoNeigh, input);
    __m512d permNeighMin = _mm512_min_pd(permNeigh, input);
    __m512d permNeighMax = _mm512_max_pd(permNeigh, input);
    input = _mm512_mask_mov_pd(permNeighMin, 0xAA, permNeighMax);
}
{
    __m512i idxNoNeigh = _mm512_set_epi64(0, 1, 2, 3, 4, 5, 6, 7);
    __m512d permNeigh = _mm512_permutexvar_pd(idxNoNeigh, input);
    __m512d permNeighMin = _mm512_min_pd(permNeigh, input);
    __m512d permNeighMax = _mm512_max_pd(permNeigh, input);
    input = _mm512_mask_mov_pd(permNeighMin, 0xF0, permNeighMax);
}
{
    __m512i idxNoNeigh = _mm512_set_epi64(5, 4, 7, 6, 1, 0, 3, 2);
    __m512d permNeigh = _mm512_permutexvar_pd(idxNoNeigh, input);
    __m512d permNeighMin = _mm512_min_pd(permNeigh, input);
    __m512d permNeighMax = _mm512_max_pd(permNeigh, input);
    input = _mm512_mask_mov_pd(permNeighMin, 0xCC, permNeighMax);
}
{
    __m512i idxNoNeigh = _mm512_set_epi64(6, 7, 4, 5, 2, 3, 0, 1);
    __m512d permNeigh = _mm512_permutexvar_pd(idxNoNeigh, input);
    __m512d permNeighMin = _mm512_min_pd(permNeigh, input);
    __m512d permNeighMax = _mm512_max_pd(permNeigh, input);
    input = _mm512_mask_mov_pd(permNeighMin, 0xAA, permNeighMax);
}

return input;
}
```

Code 1: AVX-512 Bitonic sort for one simd-vector of double floating-point values.

```
template <class IndexType>
static inline IndexType AVX_512_partition(double array[], IndexType left, …
        IndexType right, const double pivot){
const IndexType S = 8;//(512/8)/sizeof(double);

if(right-left+1 < 2*S){
    return CoreScalarPartition<double,IndexType>(array, left, right, pivot);
}

__m512d pivotvec = _mm512_set1_pd(pivot);

__m512d left_val = _mm512_loadu_pd(&array[left]);
IndexType left_w = left;
left += S;

IndexType right_w = right+1;
right -= S-1;
__m512d right_val = _mm512_loadu_pd(&array[right]);

while(left + S <= right){
    const IndexType free_left = left - left_w;
    const IndexType free_right = right_w - right;

    __m512d val;
    if( free_left <= free_right ){
        val = _mm512_loadu_pd(&array[left]);
        left += S;
    }
    else{
        right -= S;
        val = _mm512_loadu_pd(&array[right]);
    }

    __mmask8 mask = _mm512_cmp_pd_mask(val, pivotvec, _CMP_LE_OQ);

    const IndexType nb_low = popcount(mask);
    const IndexType nb_high = S-nb_low;

    _mm512_mask_compressstoreu_pd(&array[left_w],mask,val);
    left_w += nb_low;

    right_w -= nb_high;
    _mm512_mask_compressstoreu_pd(&array[right_w],~mask,val);
}

{
    const IndexType remaining = right - left;
    __m512d val = _mm512_loadu_pd(&array[left]);
    left = right;

    __mmask8 mask = _mm512_cmp_pd_mask(val, pivotvec, _CMP_LE_OQ);

    __mmask8 mask_low = mask & ~(0xFF << remaining);
    __mmask8 mask_high = (~mask) & ~(0xFF << remaining);

    const IndexType nb_low = popcount(mask_low);
    const IndexType nb_high = popcount(mask_high);

    _mm512_mask_compressstoreu_pd(&array[left_w],mask_low,val);
    left_w += nb_low;

    right_w -= nb_high;
    _mm512_mask_compressstoreu_pd(&array[right_w],mask_high,val);
}
{
    __mmask8 mask = _mm512_cmp_pd_mask(left_val, pivotvec, _CMP_LE_OQ);

    const IndexType nb_low = popcount(mask);
    const IndexType nb_high = S-nb_low;

    _mm512_mask_compressstoreu_pd(&array[left_w],mask,left_val);
    left_w += nb_low;

    right_w -= nb_high;
    _mm512_mask_compressstoreu_pd(&array[right_w],~mask,left_val);
}
{
    __mmask8 mask = _mm512_cmp_pd_mask(right_val, pivotvec, _CMP_LE_OQ);

    const IndexType nb_low = popcount(mask);
    const IndexType nb_high = S-nb_low;

    _mm512_mask_compressstoreu_pd(&array[left_w],mask,right_val);
    left_w += nb_low;

    right_w -= nb_high;
    _mm512_mask_compressstoreu_pd(&array[right_w],~mask,right_val);
}
return left_w;
}
```

Code 2: AVX-512 partitioning of a double floating-point array (AVX-512-partition)

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Evaluating Dependency based Package-level Metrics for Multi-objective Maintenance Tasks

Mohsin Shaikh
Qaid-e-Awam University of Engineering Science and Technology, Nawabshah

Adil Ansari
Qaid-e-Awam University of Engineering Science and Technology, Nawabshah

Kashif Memon
UCET, The Islamia University of Bahwalpur

Akhtar Hussain Jalbani
Qaid-e-Awam University of Engineering Science and Technology, Nawabshah

Ahmed Ali
Qaid-e-Awam University of Engineering Science and Technology, Nawabshah

***Abstract*—Role of packages in organization and maintenance of software systems has acquired vital importance in recent research of software quality. With an advancement in modularization approaches of object oriented software, packages are widely considered as re-usable and maintainable entities of object-oriented software architectures, specially to avoid complicated dependencies and insure software design of well identified services. In this context, recently research study of H. Abdeen on automatic optimization of package dependencies provide composite frame of metrics for package quality and overall source code modularization. There is an opportunity to conduct comprehensive empirical analysis over proposed metrics for assessing their usefulness and application for fault-prediction, design flaw detection, identification of source code anomalies and architectural erosion. In this paper, we examine impact of these dependency optimization based metrics in wide spectrum of software quality for single package and entire software modularization. Our experimental work is conducted over open source software systems through statistical methodology based on cross validation fault-prediction and correlation. We conclude with empirical evidence that dependency based package modularization metrics provide more accurate view for predicting fault-prone packages and improvement of overall software structure. Thus, application of these metrics can help the developers and software practitioners to insure proactive management of the source code dependencies and avoid design flaws during software development.**

***Keywords*—Software quality; package-level metrics; software modularization; fault-prediction**

I. Introduction

Software engineering is aimed at developing mechanism and tools that automates the manual operation. For the assessment of software quality, functional stability and maintainability of its design are prime objectives. Recently, packages have acquired core interest for proper organization of source code entities due to growing complexity of classes in object oriented (OO) source code paradigms. A package is relatively easier to re-use, re-factor and test, eventually reducing maintenance cost [1], [2]. There have been increasing efforts to analyze packages and their architecture in object oriented systems to determine quality attributes of object oriented source code [3], [4]. Conventionally, software evolution process has been subject to structural and architectural changes in the source code, targeting suitable and organized placement of classes in particular. However, such re-factoring practices can cause drift and deterioration in modularization quality of software [5]. Consequently, to insure flexible software modularization, optimization of package structure and their connectivity can be a vital maintenance task. In practice, if quality of package dependencies is evaluated quantitatively, then modifying its structural components to avoid potential flaws becomes easier task.

Although, there have been attempts to improve the modularization of software through heuristic search methods using decomposition techniques and deterministic procedures. These are frequently based on clustering approaches which do not address the source code design issues at precise level of granularity like, classes or packages [6], [7]. Furthermore, the existing approaches of software modularization for changing the structure of package entail costly maintenance overhead, complicating its understandability and comprehension [8], [9]. Abdeen *et al.* recently proposed a package level metrics suite which support the modularization of source code architecture using existing package structure, thus without affecting prevalent software design adversely [10].

Despite different existing efforts of proposing metrics to characterize the packages in object oriented systems, there is a need to evaluate capability of these metrics to measure intended quality attributes of software [11], [12]. In this paper, we examine the usefulness of package quality metrics proposed by Abdeen *et al.* in wide spectrum of software quality, i.e., fault-proneness, vulnerability detection, coding standard violation. We also determine the correlation of modularization metrics presented by Abdeen *et al.* with already studied modularity metrics of different application domains. In this context, First, we develop prediction model for fault-proneness of packages with logistic regression in comparison to traditional Martin package level metrics suite and linear correlation models with post-release faults (reported in standard bug repositories), vulnerabilities and coding standards are examined. Secondly, we form correlation model among different modularization metrics to understand and evaluate the their relationships and its impact over entire modularization design. Experimental results on open source software systems show that: 1) Package Quality metrics by Abdeen et al. are better candidates of fault-proneness when used in combination with Martin's metric suite in inter as well as intra releases of software systems; 2) Most of Package Quality metrics have shown reasonable association with actual post-release faults, vulnerabilities and coding standards violations detected through open source tools like *FindBugs* and *PMD*; 3) Package level Modularization metrics by Abdeen *et al.* can be used to evaluate the external strength of overall structural design from the perspective of cohesion, coupling and cyclic/acyclic dependencies. It asserts that improper handling of dependencies at package level can further deteriorate source code causing operational complexity and difficult re-usability.

The rest of the paper is organized as follows. Section 2 explains the motivation of research study in the context of Software Quality. Section 3 describes investigated metrics with their formal definitions. Section 4 provides illustrative example for comprehension of metrics computation. Section 5 presents detailed empirical study with stated research objectives, methodology and obtained results using graphical and tabular representation. Section 6 illustrates most significant related work in the literature of package level fault-prediction. Implication of research study is discussed in Section 7. Threats to validity are explained in Section 8 followed by Conclusion as Section 9.

II. Motivation

Over the years, a variety of quality models (QMs) has been proposed objectively to support the software development, through description, assessment and prediction of software quality [13]. These models evaluate quality of software systems using defined metrics. Examples of metrics-based models are Maintainability Index(MI) that determines quantitative value of maintainability [14], Modularization Quality (MQ) that evaluates cluster based cohesion or software architecture [15]. However, there is rare study over the package based design of source code for maintenance objectives. In this section, we briefly present the motivational context of our research. To achieve this, we discuss domains of these QMs relevant to our paper.

A. Static Analysis based Quality Assessment

Static analysis is carried out to analyze the source code using mainly using open source tools to discover security vulnerabilities. These vulnerabilities can cause critical system malfunction are economically harmful as well. Clearly, techniques that can reduce occurrence of bugs would be beneficial. To achieve this goal, static analysis tools have been designed to report early warnings and design anomalies. Although, their effectiveness is realized some settings, however, usefulness of warnings generated by them is still unclear. Recently, two static analysis tools FindBugs and PMD have been empirically reported to have less false positives [16] which are briefly introduced below:

1) FindBugs: FindBugs, developed by Hovemeyer *et al.*, is a tool that analyzes the java byte-code against various families of warnings characterizing common bugs in many system [17]. The main warnings provided by Findbugs are: null pointer de-reference, method not checking for null argument, close() invoked value that is always null. It actually checks the correctness, bad practice, malicious code vulnerability and performance, etc.

2) PMD: PMD is static analysis tool that finds defects, deadcode, duplicate code, sub-optimal code and overcomplicated expression, was first developed by Copeland *et al.* [18]. PMD operates over Java source code unlike FindBugs which analyzes byte-code. PMD statically warns many patterns, such as, jumbled incremented, return finally block, class cast exception, etc.

B. Prediction based Quality Assessment

These models are usually based on source code metrics or defection detection to estimate number of systems faults, failures chances and maintenance effort. Mostly, software fault proneness prediction is taken as good example of these models. Other examples include Software Reliability growth (SRGM) and modeling of processes associated with software failures [19].

III. Description of Studied Metrics

As a matter of best programming practices, software code should adhere to basic principle of high cohesion and low coupling. However, package optimization process should facilitate any structural change within current design of modularization, otherwise, subsequent decision of modification shall make software system vulnerability prone. Metrics proposed by Abdeen et al. provide an approach for automatic optimization of software modularization by minimizing the cyclic connections (direct cyclic-connectivity) among the packages. There are mainly two suites of proposed package measure, i.e., 1) for quality of single package; 2) evaluation of modularization quality on based cyclic/acyclic dependencies which are described in Tables I and II.

TABLE I. Description of Investigated Package Quality Metrics

Metric	Definition
Package Cohesion	$CohesionQ(p) = \frac{\lvert p_{Int.D}\rvert}{\lvert p_D\rvert}$
Package Coupling	$CouplingQ(p) = 1 - \frac{\lvert p_{Pro.P} \cup p_{Cli.P}\rvert}{\lvert p_D\rvert}$
Package Cyclic Dependencies	$CyclicDQ(p) = 1 - \frac{\lvert p_{Cyc.D}\rvert}{\lvert p_D\rvert}$
Package Cyclic Connections	$CyclicCQ(p) = 1 - \frac{\lvert p_{Cyc.Con}\rvert}{\lvert p_D\rvert}$

- *CohesionQ(p)*: Measures ratio of Internal Dependencies of package to all dependencies among and within a package.
- *CouplingQ(p)*: Measures ratio of package providers and clients to all dependencies among and within a package.
- *CylicDQ(p)* : Measures ratio of class cyclic dependencies within the package to all dependencies of package.

- *CylicCQ(p)* : Measures ratio package cyclic connections among the packages to all dependencies of package.

TABLE II. DESCRIPTION OF INVESTIGATED PACKAGE MODULARIZATION METRICS

Metric	Definition
Inter-Package Dependencies	$IPD = \sum_{i=1}^{\lvert\mathcal{M}_p\rvert} \lvert p_{i_{Ext.Out.D}} \rvert$ $ICD = \sum_{j=1}^{\lvert\mathcal{M}_c\rvert} \lvert c_{j_{Out.D}} \rvert$ $CCQ(\mathcal{M}) = 1 - \frac{IPD}{ICD}$
Inter-Package Connections	$IPC = \sum_{i=1}^{\lvert\mathcal{M}_p\rvert} \lvert p_{i_{Out.Con}} \rvert$ $CRQ(\mathcal{M}) = 1 - \frac{IPC}{ICD}$
Inter-Package Cyclic Dependencies	$IPCD = \sum_{i=1}^{\lvert\mathcal{M}_p\rvert} \lvert p_{i_{Out.Cyc.D}} \rvert$ $ADQM(\mathcal{M}) = 1 - \frac{IPCD}{ICD}$
Inter-Package Cyclic Connections	$IPCC = \sum_{i=1}^{\lvert\mathcal{M}_p\rvert} \lvert p_{i_{Out.Cyc.Con}} \rvert$ $ACQM(\mathcal{M}) = 1 - \frac{IPCC}{ICD}$

- $CCQ(\mathcal{M})$: measures common closure of modularization for the classes that change together among the packages.
- $CRQ(\mathcal{M})$: measures common reuse of modularization for package that are are reused together.
- $ADQ(\mathcal{M})$: measures the extent of modularization to which cyclic dependencies between the classes are minimized.
- $ACQ(\mathcal{M})$: measures the extent of modularization to which cyclic connections among the package are minimized .

Table I summarizes formal definitions of above mentioned metrics. All theses metrics are based on relationships established among the software entities through direct/indirect and cyclic/acyclic dependencies established through classes and packages. Abdeen et al. has described utility of these metrics in addressing following optimization challenges in packages.

1) Inter-connections among the classes of large application create complex design and also increase inter-package connectivity.
2) Inadequate distribution of classes may result in highly complex afferent coupling on particular package, hence, violating the basic design rules of package, i.e, domain, size and coding practice.
3) Minimization of package dependencies may also degrade other packages.

Table II describes modularization metrics proposed by Abdeen *et al.* These modularization metrics were specifically formulated to address the prevalent modularization limitations which mainly focused on changing the structural shape of software from the scratch. Where as, metrics presented in Table II have goal of multi-objective optimization for improving existing package structure in accordance with well-known design principles. Thus, these metrics bear unique importance in automatic software re-modularization while respecting original design decisions.

Martin metrics suite has been defined in Table IV which have been already used as *Baseline* in many package level bug prediction studies [20], [21]. Table V presents the definitions of modularization metrics studied by Lee et al. [22]. The main objective of their research was to analyze and compare the various modularity metrics that have been studied in different domains. We set this research work as baseline to further investigate the applicability of package based modularization proposed by Abdeen *et al*. Below we summarize the definitions, notations used in definitions and interpretation of these metrics in particular context of study by Lee *et al.*. [22]. They have conducted an experimental evaluation of these metrics on evolutionary software and reported correlation of different modularity metrics and their sensitivities towards particular modular factors.

TABLE III. DESCRIPTION OF NOTATIONS USED TABLES I AND II

Metric	Definition
$p_{Int.D}$	Unique internal dependencies present within the package.
$p_{Pro.P}$	Unique provider dependencies of package p.
$p_{Cli.P}$	Unique client dependencies of package p.
$p_{Cyc.D}$	Unique cyclic dependencies produced through classes of modularization.
$p_{Cyc.Con}$	Unique cyclic dependencies produced using packages of modularization.
$p_{i_{Ext.Out.D}}$	Unique inter-package dependencies going out from package p.
$p_{i_{Out.Con}}$	Unique inter-package external connections from package p.
$c_{j_{Out.D}}$	Inter-class dependencies going outside the package p.
$p_{i_{Out.Cyc.D}}$	out-going cyclic dependencies produced through classes from package p.
$p_{i_{Out.Cyc.Con}}$	out-going cyclic dependencies produced through packages from package p.

TABLE IV. DESCRIPTION OF MARTIN METRIC SUITE

Metric	Definition
N	Class entities: The number of concrete, abstract classes and interfaces in the package.
Ca	Afferent Coupling: The number of other packages that depend upon classes within a package.
Ce	Efferent Coupling: The number of other packages that other class in a package depend upon.
A	Abstractness: The ratio of abstract classes in package to total number classes in a package.
I	Instability: The ratio of Efferent Coupling to total Coupling, $I = \frac{Ce}{(Ce+Ca)}$.
D	Distance: The distance from the main sequence: $D = \lvert A + I - 1 \rvert$.

TABLE V. BASELINE MODULARIZATION METRICS STUDIED IN DIFFERENT DOMAINS

Reference	Definition
Modularity and community structure in network[23]	$M_{newm} = \frac{1}{2m} \sum_i \sum_j \left(A_{ij} - \frac{k_i k_j}{2m} \right) \delta(g_i, g_j)$
Modularity of software based on clustering[15]	$MQ = \sum_{i=1}^{k} \frac{2\mu_i}{2\mu_i + \sum_{j=1}^{k} (\epsilon_{i,j} + \epsilon_{j,i})}, \quad M_{bunch} = \frac{MQ}{k}$
Modularity of mechanical products. [24]	$M_{g\&g} = \frac{\sum_{k=1}^{M} \frac{\sum_{i=n_k}^{m_k} \sum_{j=n_k}^{m_k} R_{ij}}{(m_k - n_k + 1)^2} - \sum_{k=1}^{M} \frac{\sum_{i=n_k}^{m_k} \left(\sum_{j=1}^{n_k - 1} R_{ij} + \sum_{j=m_k+1}^{N} R_{ij} \right)}{(m_k - n_k + 1)(N - m_k + n_k - 1)}}{M}$
Modularity based on dependency cost[25]	$M_{rcc} = 1 - \sum_{i=1}^{N} \sum_{j=1}^{N} \frac{DependencyCost(i,j)}{N^{2\lambda}}$

- ***M*** $_{newm}$: This metric is well known approach for quantifying modularity of social network represented in graphical structures. Recently, there has been extensive focus on application of this metric into studies pertaining different scientific domains, specially, social network, metabolic network, neural network and the World Wide Web. Computation of metric is based on theoretical heuristic that edges (links between nodes) within a module (community) are greater than expected ones. Further, in the definition, i and j are nodes, A_{ij} represents edges between nodes. m is the number of total edges and k_i indicates expected number of edges in node i. δ is a comparator function that it outputs 1 where its two parameters are same, 0 otherwise. g_i, parameter of δ, represents the module containing node i. This metric ranges between 1 as best value and 0 as worst value.
- ***M*** $_{bunch}$: This metric is normalized version of clustering factor (MQ) introduced by Mancoridis textitet al.. [15]. MQ is the most frequently used method for evaluation of a software modularity. μ_i is representation of

intra-edges of module i, while $\epsilon_{i,j}$ denotes inter-edges between modules i and j in total number of modules k.

- $\boldsymbol{M_{g\&g}}$: This metric was formulated to measure the modularity of complex mechanical products. However, their application in software systems can be interesting towards incorporating mechanical engineering principles and software design theories. Basically, metric quantifies modularity of physical entities using difference of inter and intra edge densities. In the definition, M is number of modules and N is number of mechanical components (total software nodes in our context of study). The numerator of the fraction consists of two part, the sum of intra-edge density of modules and the sum of inter-edge density of the modules. Symbols, i.e., n_k and m_k are the indexes of first node and last node respectively in module k. R_{ij} denotes row and column in dependency between node i and j (software nodes).
- $\boldsymbol{M_{rcc}}$: This metric has its basic application in measuring the modularity of evolving software systems. Computing the Relative Clustered Cost of software systems is key idea of this metric. In perspective of software architectures, software systems having no dependencies shall bear the value 0 and 1 in case of all inter-dependent nodes. *DependencyCost* function returns a weighted dependency between node i and j. N is the number total nodes, n is the size of module, λ is a user defined parameter for the metric. The weight varies along with the dependency types. If a dependency between i and j is an intra-dependency of a single module, the weight is n^{λ}, where n indicates the number of nodes in the module. On the other hand, if it is an inter-dependency between separate modules, the weight becomes N^{λ} to have considerable penalty in terms of poor coupling.

IV. Working Example

Consider an example of four packages connected through different dependencies as shown in Fig. 1. To simplify the working mechanism of Abdeen et al.'s metrics, we illustrate dependencies by package p with other packages in modularized design.

In Fig. 1, package p forms four kinds of dependencies with four other packages; Internal dependencies which is within the classes of package p, external dependencies which connect classes of package with other four packages, cyclic dependencies which goes out of classes of package p and return to same classes of package p, cyclic connections which form cycle between package p and other package in the modularization design.

It can be seen from Fig. 1, package p contains five internal dependencies within classes $C1, C2, C3, C4$. Also, it can be visualized that there are 7 external incoming dependencies of package p from the classes, i.e., $(C31, C32, C41, C23, C21, C52)$ and it contains five external outgoing dependencies towards the classes, i.e., *(C31, C41, C42, C21, C23, C52)*. Among external dependencies, four dependencies produce the cycle between package p and other packages, i.e., *(C3, C31), (C3, C31, C32), (C4, C41), (C1, C52, C2)*. Similarly, these external dependencies create three cyclic connections $(p, p1), (p, p3), (p, p4)$. On the basis of definitions of Abdeen *et al.*'s metrics, Table VI presents metrics computation of modularization design of packages p shown in Fig. 1.

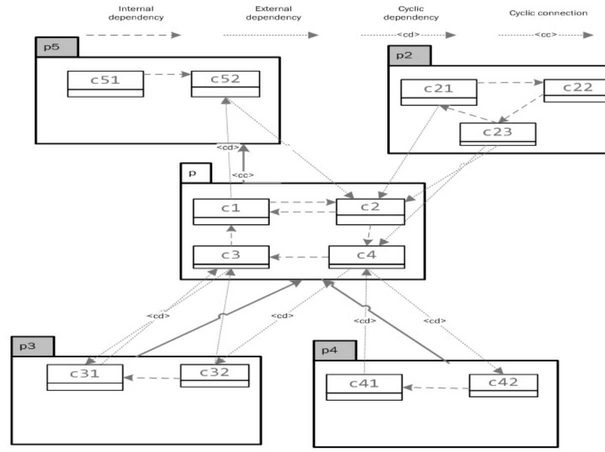


Fig. 1. Example of packages having inter and intra dependencies.

TABLE VI. Computation of Abdeen *et al.'s* Metrics

Metric	Computation
$CohesionQ(p)$	$\frac{\lvert C1+C2+C3+C4 \rvert}{\lvert C1+C2+C3+C4+C31+C32+C41+C23+C21+C52+C42 \rvert} = (4/11)$
$CouplingQ(p)$	$1 - \frac{\lvert (C52+C41+C31+C42) \cup (C52+C21+C23+C41+C32+C31) \rvert}{\lvert C1+C2+C3+C4+C31+C32+C41+C23+C21+C52+C42 \rvert} = (7/11)$
$CyclicDQ(p)$	$1 - \frac{\lvert (C3+C31+C32+C1+C2+C52+C4+C41+C42) \rvert}{\lvert C1+C2+C3+C4+C31+C32+C41+C23+C21+C52+C42 \rvert} = (9/11)$
$CyclicCQ(p)$	$= 1 - \frac{\lvert (P3+P5+P4) \rvert}{\lvert C1+C2+C3+C4+C31+C32+C41+C23+C21+C52+C42 \rvert} = (3/11)$

V. Empirical Study

In this section, we describe the methodology used to analyze the metrics on open source software systems. The analysis procedures for empirical evaluation involve descriptive structural information of subject systems, statistical analysis, linear correlation and logistic regression analysis. An overview of data processing steps are introduced in Fig. 2. The first step is to mine the source code of subject systems from repositories and archives. Second step is to apply three pronged static analysis of source code files through: 1) Understand [1], commercial static analysis tool for re-engineering and maintenance the software that provides metrics information of parsed code; 2) FindBugs [2] that identifies high priority warnings in the source code; 3) PMD [3] an extensive cross language static code analyzer that reports high priority coding rule violations. Step three is mapping of post-release faults from bug repositories, dependency based metrics and high priority source code violation warnings against package entities of corresponding source code file to compose the data-sets. In fourth step, data analysis techniques are used to build prediction models and determine the relationships among the modularization metrics. Finally, fifth step reports performance of models.

[1]https://scitools.com/
[2]http://findbugs.sourceforge.net/
[3]https://pmd.github.io/

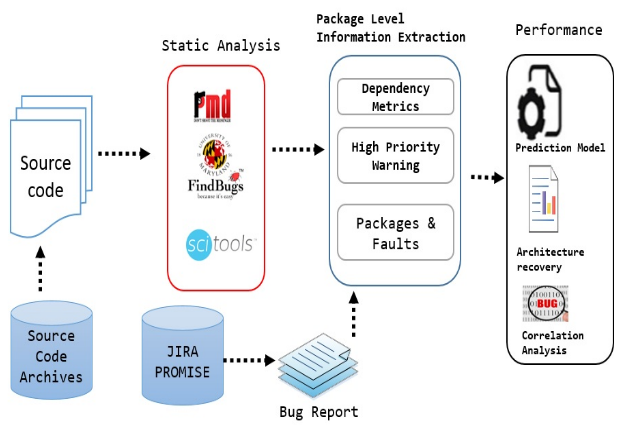


Fig. 2. Data processing mechanism.

A. Research Objectives

In particular, our research is directed to explore following implications of inter and intra-package dependencies as salient objectives.

1) Cyclic dependencies among the packages are anti-patterns and may cause design flaws or make packages fault-prone.
2) Directed dependencies can provide composite view of package coupling and package cohesion which are yet evolving concepts for package entities of source code.
3) Automatic package optimization improve overall modularization quality of software.

Above mentioned challenges require evaluation of metrics through rigorous process of software quality. This can be achieved, if described metrics may succeed to provide complementary view of source code, consequently strengthening structural and functional validity of software design through proactive decision making. Another aspect of this study is to investigate relationship among Abdeen's modularization metrics solution based on package optimization and *Baseline* modularization approaches described in Table III. Our assessment criterion are formed on the basis of notion that proposed modularization can provide better illustration of *Baseline* approaches through different dimensions (e.g., Cyclic dependencies minimization, intra-package dependencies maximization), eventually, help developer's decisions to adhere with design principles during software development.

B. Experimental Methodology

In this section, we provide a brief overview of statistical techniques and mechanism of their application in our study.

1) Correlation Analysis: The correlation analysis aims to determine relationship among variables. The correlation coefficient is measure of linear association between two variables. For this purpose, Spearman's rank correlation is widely performed over nonparametric nature of software metrics. The significance of correlation is tested at different levels of confidence interval 95%, i.e., $p - value < 0.05$.

2) Multivariate Logistic Regression:: Logistic regression is standard statistical modeling technique in which the dependent variable can take on one of two different values: 0 and 1. A multivariate logistic regression model is based on the following relationship equation:

$$Pr(Y = 1|X_1, X_2, ...X_n) = \frac{e^{\alpha+\beta_1 X_1+\beta_2 X_2+..\beta_n X_n}}{1+e^{\alpha+\beta_1 X_1+\beta_2 X_2+..\beta_n X_n}}$$

Where, $X_1, X2..., X_n$ are independent variables, i.e., characteristics describing the source code(package level metrics), $Pr(Y = 1|X_1, X_2, ...X_n)$ represents the probability that the dependent variable $Y = 1$, i.e., the extent of package predicted as faulty.

3) Classification: Classification methodology is applied to predict weather a package is faulty or not. Various studies have set confusion matrix as benchmark to evaluate the performance of models and analyze the prediction capability of independent variables. From the confusion matrix, following two popular accuracy measures are computed to conduct the evaluation. All our prediction models output probabilities of fault-proneness of package entities. To classify a package as faulty, varying thresholds on probability are utilized. Thus, different choices of threshold will produce varying rates of *false* positives/negatives (FP/FN) and *true* positives/negatives (TP/TN).

- *Accuracy (Acc.)*: Measures the proportion of correct predictions. Accuracy is defined as: $Acc = \frac{TP+TN}{TP+TN+FP+FN}$.
- *Precision (Pr.)*: Measure of exactness, defines probabilities of true faulty packages to the number of package predicted as faulty. Precision is defined as $Pr = \frac{TP}{TP+FP}$.
- *Recall (Rec.)*: Measure of completeness, defines the probabilities of true faulty packages in comparison to total number of faulty packages. Recall is defined as $Rec = \frac{TP}{TP+FN}$.
- *F-measure (F1.)*: Measures harmonic mean of precision and recall of predicted model. $F1 = \frac{2*Pr.*Rec.}{Pr.+Rec.}$.

We build Logistic Regression (LR) model to predict the fault-proneness of Abdeen's metrics (*AbdeenMod*) and comparative analysis is carried out against the Martin's package level metrics (*RM*). Further, statistical association is used to discover the impact of dependencies over design anomalies (null pointer de-references, infinite recursive loops, bad uses of java libraries) and common programming flaws (unused variable, unnecessary object creation). The correlation analysis aims to determine significant relationship of each of metric described in Table I with quality attributes of source code. According to recent survey, logistic regression is most commonly used and productive technique for fault-prediction performance in software engineering [26].

C. Data Sets

Basically, there are two different types of data-sets formed for experimental work for each category of metrics. We tend to follow the research based perspectives of taking into account subjects (software systems) of varying nature, i.e., with large

TABLE VII. STRUCTURAL INFORMATION OF SUBJECT SYSTEMS

System	Versions	Number of Packages	Total Number of faults	Faulty Packages	Percentage of Faulty packages	FB-Warnings Priority-1	PMD-Warnings Priority-1
Eclipse	2.0	377	917	190	50%	551	422
Eclipse	2.1	428	657	193	45%	720	5365
Eclipse	3.0	642	1523	307	47%	356	7002
POI	2.5	74	107	15	20%	96	2601
POI	3.0	80	316	30	38%	175	3743
Camel	1.6	210	144	23	62%	27	148
JDTCore	3.4	46	47	32	47%	159	931
Lucene	2.4	42	318	34	80%	82	879
jEdit	4.2	28	14	12	42%	115	363
jEdit	4.3	37	19	6	16%	109	485

and small size of packages, with diverse domain of application and already utilized in research literature of software quality. For package quality metrics, seven releases of 3 different open source software systems and four other open source software releases were considered. Eclipse[4]: An Integrated Development Environment (IDE) for software development in collaborative working groups. jEdit[5]: A mature programmer's text editor, written in java and an extensible plug-in architecture. POI [6] a powerful tool to read and write MS Excel files in Java. Lucene [7] provides java based indexing and search technology. JDT-Core[8] is an infrastructure of eclipse IDE. In total 10 data-sets are formed. Each data-set comprises of 6 traditional package-level metric described by R.C Martin [2],4 package quality metrics defined by Abdeen et al. [10] for fault-proneness of packages, source code bug warnings of priority 1 identified by FindBugs and code rules violation warnings of priority 1 reported by PMD.

It can be well inferred that meaningful statistical conclusions can be drawn, as data-sets encompass diverse domains of architectural composition. Post-release fault data of subjects was obtained from public repositories, i.e., Eclipse Bug Data [9] and PROMISE[10]. For package modularization metrics, experiment study consists of 23 versions of two different open source software systems. JHotDraw [11]: is a Java GUI framework for technical and structured Graphics. Ant[12]: is a Java library and command-line tool whose mission is to drive processes described in build files. These data-sets have been already studied in comparative modularity analysis by Lee et al. [22]. Therefore, we utilized same data for 4 well-known clustering based modularity metrics in our study part of modularity analysis. However, all the *AbdeenMod* metrics (package quality and package modularization) were computed by our own scripts developed through Understand-Perl API[13] with utmost reliance and incremental testing (Made available public ally at site[14]).

Table VII provides a summarized description of the data-sets in our experimental study. It mainly represents system name with release version, number of total packages, total Number of faults, number of highest priority design flaws detected through FindBugs[15] and source code violations having

[4]https://eclipse.org/
[5]http://www.jedit.org/
[6]https://poi.apache.org/
[7]https://lucene.apache.org/
[8]https://eclipse.org/jdt/core/
[9]https://www.st.cs.uni-saarland.de/softevo/bug-data/eclipse/
[10]http://openscience.us/repo/issues/bugfiles.html
[11]http://www.jhotdraw.org/
[12]http://ant.apache.org/
[13]https://scitools.com/feature/api/
[14]https://github.com/Analyzer2210cau/Cyc-Deps-Maintainence-Objectives
[15]http://findbugs.sourceforge.net/

TABLE VIII. INTRA-RELEASE PREDICTION MODELS: COMPARISON

System	*RM*		*AbdeenMod+RM*		Improved
	Acc. (mean)	**F1.** (mean)	**Acc.** (mean)	**F1.** (mean)	**%age**
Camel-1.6	0.88	0.40	0.90✓	0.50	1.1%
Eclipse-2.0	0.60	0.46	0.68✓	0.64	13.3%
Eclipse-2.1	0.59	0.38	0.62✓	0.40	5%
Eclipse-3.0	0.64	0.50	0.66✓	0.54	3%
JDTCore-3.4	0.77	0.84	0.76	0.77	–
Lucene-2.4	0.83	0.56	0.84	0.53	–%
POI-2.5	0.67	0.65	0.62	0.42	-7%
POI-3.0	0.75	0.5	0.77✓	0.6	2.6%
jEdit-4.2	0.68	0.77	0.78✓	0.83	14.7%
jEdit-4.3	0.82	0.4	0.80	0.3	–%

TABLE IX. INTER-RELEASE PREDICTION MODELS: COMPARISON

System	*RM* (Acc)	*AbdeenMod+RM* (Acc)	%Improvoed
Eclipse-2.0(Train), Eclipse-2.1(Test)	0.65	0.67✓	3%
POI-2.5(Train), POI-3.0(Test)	0.57	0.75✓	31%
jEdit-4.2(Train), jEdit-4.3(Test)	0.60	0.59	-2%

highest priority identified through PMD [16] in corresponding software. Both of these tools are extensively used in source code analysis with recognition in software industry and research pertaining to software quality [27].

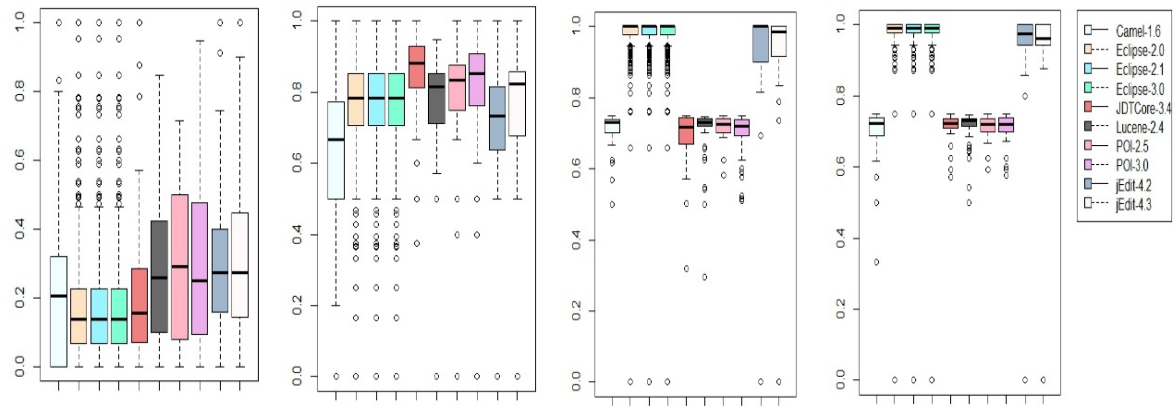
D. Experimental Results

This section briefly illustrates experimental results and analysis on both categories of metrics. In our empirical evaluation, our focus is to obtain maximum possible statistical significance for the research objectives defined in earlier section.

1) Package Quality Metrics: Fig. 3 depict the box-plot to describe the distribution of four package-quality metrics in each data-set. Box-plot range distribution of *CohesionQ* and *CouplingQ* lies within 25 to 75 percentile as shown in Fig. 3. It can be observed that *CohesionQ* metric has low median ($value \approx 0.15$) for three versions of eclipse, however, it is almost in even distribution for all versions of jEdit ($value \approx 0.3$). On the contrary, *CouplingQ* values seem to be distributed with quite high median ($value \approx 0.75$) for all the versions of data-sets. It depicts the fact that high coupling and low cohesion trend is found in almost all data-sets of our study, employing potential threat of packages being faulty quite high. Similarly, values of *CyclicCQ* and *CyclicDQ* are relatively with very high median ($value \approx 0.95$) compared to other two metrics. Whereas, distribution of *CylicCQ* and *CyclicDQ* range within 25 to 75 percentile as shown in Fig. 3, showing presence of high inter-package cyclic dependencies and connections in all the data-sets.

Table VIII summarizes detailed information of fault-prediction model built on the basis of intra-release test and train data-sets. Results obtained from 10 times 10-fold cross-validation for two models *RM* and *AbdeenMod+RM* using LR are presented in Table VIII. It can be clearly observed that there is substantial accuracy improvement while classifying the *AbdeenMod+RM* model against *RM*(Baseline) model in most of cases (indicated with ✓). From Table VIII, we make following observations. First, *AbdeenMod+RM* models for data-set with higher number of packages have easily

[16]https://pmd.github.io/



(a) *CohesionQ(p)* (b) *CouplingQ(p)* (c) *CyclicCQ(p)* (d) *CyclicDQ(p)*

Fig. 3. Box plot representation of metrics for all data-sets.

outperform traditional approaches of fault-prediction which is case with three versions of Eclipse (2.0, 2.1, 3.0) and Camel-1.6. Second, if data-set contains small number of packages then prediction may result adversely which is the case with jEdit-4.3 and JDTCore-3.4 where accuracy is not improved with *AbdeenMod+RM* model. Third, *AbdeenMod+RM* model's highest accuracy improvement was reported as 14.7%, making the application of cyclic dependency metrics quite significant for fault-proneness prediction. F1-score is another dimension of performance measure that takes int account both precision and recall. Mean accuracy of successful models in Table VIII has been seen in range of $0.83 \approx 0.40$ (indicated with ✓). Despite the accuracy improvement in some of cases, F1-score is still unsatisfactory in some cases, e.g., Lucene-2.4, implying lesser precision of *AbdeenMod+RM*. Generally, prediction result has been improved by 13.3% as maximum value in Eclipse (Larger data-set) and 14.7% as maximum value in jEdit (Relatively smaller data-set).

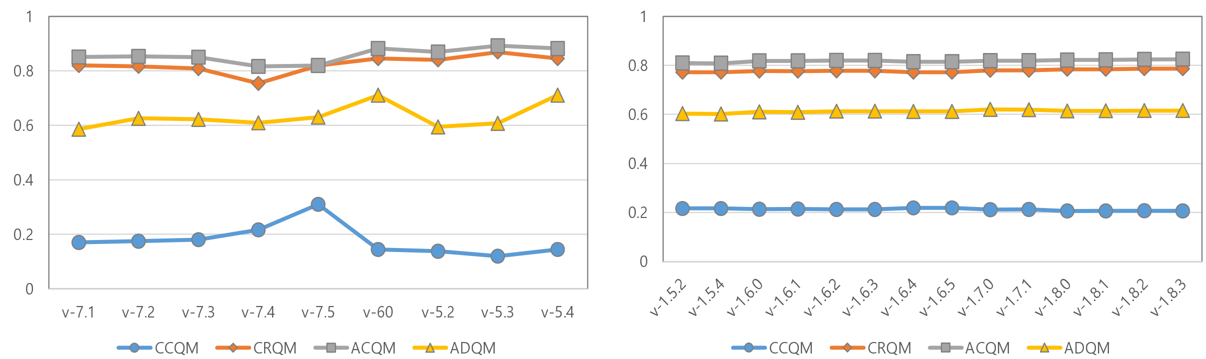
Table IX presents summary of fault-prediction model using inter-release frame which is more rigorous approach of developing train and test data-sets. Table IX mainly shows values of accuracy measure for fault-prediction model across releases of Eclipse, POI and jEdit. Clearly, prediction results with *AbdeenMod+RM* achieved competitive accuracy in two cases (indicated with ✓) as shown in Table IX and is recorded with 31% of maximum improvement. Table X shows analysis carried out over the linear correlation of each Abdeen's Package Quality metrics with number of post-release faults, coding violation and anomalies warnings of priority-1 using FindBugs and source code vulnerabilities arnings of priority-1 using PMD in corresponding package for each dataset. Significant magnitude of association is indicated with $(^{*})$ evaluated at $p - value < 0.05$ as thresh-hold. Findings of Table X can lead following inferences: First, *Cohesion* metrics exhibits significantly negative correlation as observed in most of the cases except Lucene and JDTCore. Second, statistical significance of all the package quality metrics was observed frequent in data-sets with larger number of packages, e.g., (Eclipse, POI, Camel). Third, coupling metric *CouplingQ* exhibits statistically significant magnitude of correlation with post-release faults in most of the data-sets. Fourth, statistical significant correlation of *CyclicDQ(p)* and *CyclicDQ(p)* metrics is not witnessed frequently with the exception of Eclipse-2.0. Another objective was to determine the relationship of all *AbdeenMod* metrics with design flaws and vulnerabilities detected *PMD* or *FindBugs*. Interestingly all the *AbdeenMod* metrics show the positive or negative association, but, their statistical significance is rarely observed in all cases. However, *Cohesion* and *CouplingQ* metrics have managed to develop correlation significance to considerable extent with data-sets, like (Eclipse, POI, jEdit), adding an evidence to soundness of study. On the contrary *CyclicCQ* and *CyclicDQ(p)* are not found correlated with with FB and PMD. Such findings lead to implication that design anomalies detected through open source tools like *FindBugs*and *PMD* have relatively substantial influence over package quality metrics, however, lack impact in comparison to actual post release faults.

2) Modularization Metrics: In Table XI, degree of modularization correlation between Abdeen's modularization metrics solutions and *Baseline* modularization metrics is presented. Values inside the visualization table show the magnitude of association in corresponding cell of metric at the significant level denoted as: $p - values(0.001, 0.01, 0.05, 0.1) \Leftrightarrow$ symbols("***", "**", "*", "."). For further illustration, Fig. 4(a) and (b) show overall correlation among the modularity metrics through visualization table representation for JhotDraw and Ant data-sets respectively. Distribution of each variable is shown on the diagonal with bi-variate scatter plot. As described earlier, impact of cyclic or direct dependencies is relatively considered as an anti-pattern, hence, negative correlation can be expected in our analysis.

There are some unique implications which can be formed from modularity analysis of each data-set. For JHotDraw, $CCQ(\mathcal{M})$ $ADQ(\mathcal{M})$ and $CRQ(\mathcal{M})$ exhibit complementary view of strong association with modularity metrics except $\mathbf{M}_{g\&g}$. On the contrary, $ACQ(\mathcal{M})$ is found with less association in

TABLE X. Magnitude of Correlation of Package Quality Metrics in Eclipse

Metric	*CohesionQ(p)*			*CouplingQ(p)*			*CyclicCQ(p)*			*CyclicDQ(p)*		
	Faults	FB	PMD	Faults	FB	PMD	Faults	FB	PMD	Faults	FB	PMD
Eclipse-2.0	**-0.03**	**0.27***	**0.14****	**0.18***	**-0.39***	0.23	**-0.25***	-0.038	0.47	**-0.25***	-0.038	0.47
Eclipse-2.1	–0.03	0.03	**0.14****	**0.18*****	**0.15****	**0.24*****	0.06	0.045	0.04	0.076	0.052	0.068
Eclipse-3.0	-0.024	**0.14*****	0.015	**0.22*****	**0.17*****	**0.14*****	0.06	0.05	0.03	**0.089***	0.063	0.052
JDTCore-2.4	-0.012	- 0.016	-0.15	**0.30***	**0.33***	0.083	-0.20	-0.13	0.024	0.17	0.20	0.081
Lucene-3.0	0.034	- 0.049	0.000092	0.17*	-0.11	0.083	0.047	-0.044	0.0016	0.092*	-0.094	0.083
POI-2.5	**0.33***	**0.35***	**0.34***	0.19	0.21	0.23	**0.36***	0.074	0.098	0.095	0.011	0.24
POI-3.0	0.20	**0.31***	0.20	0.20	**0.23***	**0.27****	0.053	0.067	0.12	0.087	0.11	0.14
Camel-1.6	**0.43****	**0.23***	0.33	**0.39****	**0.41****	0.058	0.0550.036	0.052	0.054	0.04	0.059	0.13
JEdit-2.0	**-0.23***	**0.49***	0.33	**0.34***	**0.48***	**0.40***	-0.020	0.047	-0.12	0.086	0.19	0.12
JEdit-2.5	**-0.25***	0.14	0.095	**0.29***	**0.35***	**0.31***	0.026	0.074	0.028	0.095	0.16	0.12



(a) *JHotDraw* (b) *Apache-Ant*

Fig. 4. Box-plot representation of Cohesion and Coupling metrics in each data-sets.

TABLE XI. Correlation Coefficient of Modularity Metrics

Project		$\mathbf{M}_{newm}$	$\mathbf{M}_{bunch}$	$\mathbf{M}_{g\&g}$	$\mathbf{M}_{rcc}$
JHotDraw(9)	$CCQ(\mathcal{M})$	**0.77***	**0.64**$^{\cdot}$	0.33	**0.72***
	$CRQ(\mathcal{M})$	**-0.80****	**-0.68***	-0.25	**0.69***
	$ADQ(\mathcal{M})$	**-0.89****	**-0.69***	-0.19	**0.76***
	$ACQ(\mathcal{M})$	-0.25	0.14	**0.67***	–
Apache-ant(14)	$CCQ(\mathcal{M})$	-0.08	**-0.78*****	**-0.79*****	**-0.74****
	$CRQ(\mathcal{M})$	0.18	**0.84*****	**0.86*****	**0.84*****
	$ADQ(\mathcal{M})$	0.38	**0.70****	**0.74****	**0.87*****
	$ACQ(\mathcal{M})$	0.21	**0.74****	**0.79*****	**0.89*****

terms of statistical significance as shown in Table XI. These indications are evident for the presence of less cyclic dependencies and cohesiveness of packages. On the other hand, for Ant data-set, $CCQ(\mathcal{M})$ and $CRQ(\mathcal{M})$ are seen to have strong negative and positive correlation with our baseline modularity metrics respectively. Whereas $\mathbf{M}_{newm}$ is an exception to reveal any prominent significance. However, $ACQ(\mathcal{M})$ and $ADQ(\mathcal{M})$ exhibit strong positive correlation with our bench mark modularity metrics as shown in Table XI. Another perspective of this dependence among multiple variables reveal that all the Abdeen's modularization are significantly related with each other as shown in Fig. 4(a) and (b). More importantly, $CCQ(\mathcal{M})$, $CRQ(\mathcal{M})$ and $ADQ(\mathcal{M})$ depict a strong positive correlation with M_{bunch} which is considered as most efficient modularity measure in software quality evaluation.

VI. Related Work

Some research studies have used package level metrics in evaluation of software quality and bug prediction. D'Ambros proposed coupling based technique for package understandability and their evolution [28]. Wilhelm et al. proposed package dependencies management and control using Martin and size metrics. Additionally, Reibing utilized these metrics to build Object-Oriented Design Model (ODEM) for formalization of design metrics [29]. It is worth mentioning that Abdeen *et al.* continued their effort to propose metrics for improving modularization, but, scope of their study was for entire modularization not for a single package [30]. However, exploring the relationship between package level metrics and external quality attributes is yet an interesting research subject. Gupta et al. presented empirical evaluation for package coupling as indicator of its understandability and maintenance [31]. Elish explored utility of Martin metrics as determinants of package understandability. He determined that almost all the Martin metrics have significant correlation with effort required to understand the package design [32]. Zimerman et al. collected fault data and complexity metrics for Eclipse releases 2.0, 2.1 and 3.0 at package level [33]. They successfully derived fault-proneness of packages by constructing logistic and linear regression models.

As a matter of observation, size and complexity metrics can not produce enough information on fault-prediction. There are certainly opportunities to explore other structural properties of packages to achieve an improved prediction accuracy. Taking this direction, Elish developed comparative inter and intra-release prediction models using CK, MOOD and Martin metrics suite [34]. Another notable study in recent time is by Zhao et al. [21], who has further endorsed the utility of package level metrics. He presented an empirical analysis for package modularization proposed by Sarkar et al. [35] metrics as having significant association with fault-proneness. All these efforts form the motivation of our study to further investigate dependency based structural properties of packages. In particular, study extends the evidence for role f package based design in improvement of fault-prediction and effectiveness in describing software quality attributes [36], [37].

VII. Discussion

Abdeen *et al.* extended their research work on the basis of package entities in proceeding years. Admittedly, each of their research effort was unique in terms of application and theoretical rationale. Similarly, modularization metrics described in Table V were studied for correlation among themselves, which required further exploration too. Therefore, our work differs in the context of application to determine modularity of Abdeen *et al.* in relation with these metrics. Following features makes our study distinctive and useful for research community.

- Adding an evidence of relationship between code metrics and design rules by static analysis tools.
- Empirical evaluation of package entities as effective de-bugging components.
- Providing the rationale that maintenance is multi-objective phase using techniques of modularity enhancement, fault-proneness prediction and source code design improvement.

Aforementioned aspects our this research study basically set novelty and technical significance for assuring quality software design and functioning. This study can help software quality engineers to prioritize their tasks.

VIII. Threats to Validity

In empirical software engineering research, use of open source and limited software projects often account for external threats to validity. However, software systems used in our study are state-of-the-art in research literature of software quality bearing an abstract representation of software structure. Since, dependency information extracted in our study can be characteristics of any industrial based operational software, the reported results can be helpful in forming a generalized opinion to reasonable extent. Although, use of more industrial based software systems can mitigate the threat of external validity. Another aspect of computation which is likely to create threats to construct and external validity, is use of *FindBugs* and *PMD*. Unfortunately, the performance of these tools are dependent on particular experimental environmental setup and system configuration. Therefore, false positives in static analysis results can't be ruled out. Similarly, measurement of metrics and their experiment through use of tools for analysis and programming have their specific limitation like, language dynamics and precision of statistical computation. However, results were acquired with maximum possible programming reliance and analysis confidence to avoid any internal threats.

IX. Conclusion

In this paper, we evaluated the impact of dependency based Package-Quality metrics towards software quality assurance. Our study validates the computation of these metrics on open-source software. Inter-release and intra-release of predictive models were constructed to conclude following: 1) Dependency based Package Quality metrics in combination with traditional package level metrics provide complementary view of fault-proneness of packages. It employs proper management and organization of packages by minimizing the dependencies can enhance the quality and ensure functional stability of software; 2) Comprehensive assessment of post-releases of software can be obtained with dependency based Package Quality metrics to avoid future potential bugs; 3) Dependency based Cohesion and Coupling metrics value improvement can help to keep the software systems up to coding standards and design rules.

The results indicate that prediction models developed with *AbdeenMod+RM* metrics achieved reasonable accuracy against *RM* metrics and traditional metrics are outperformed in fault-prediction modeling. Thus, recommendation of collecting dependency information can be significant towards software maintenance. In addition to obtained improved prediction accuracy compared to traditional model, *AbdeenMod* metrics show notable correlation with number of faults in the packages. These results also indicate that dependencies of source code at package level should be properly managed and resolved to depict the reliable software design. We also investigated the numerical relationship between Abdeen's modularization metrics and widely used modularization metrics. Our statistical computation through correlation matrix indicates that these metrics can be applied in quality assurance framework of object oriented software systems. This study has made vital contribution and provided an insights into early prediction of faults in packages through empirical evidences and statistical validations. In future, we aim to derive more metrics and explore the their relationships in other software quality attributes. In addition to this, comparative analysis using effort aware fault-prediction models is research domain to be explored in future.

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Emotion Recognition based on EEG using LSTM Recurrent Neural Network

Salma Alhagry
Faculty of Computer and Information
Cairo University
Cairo, Egypt

Aly Aly Fahmy
Faculty of Computer and Information
Cairo University
Cairo, Egypt

Reda A. El-Khoribi
Faculty of Computer and Information
Cairo University
Cairo, Egypt

***Abstract*—Emotion is the most important component in daily interaction between people. Nowadays, it is important to make the computers understand user's emotion who interacts with it in human-computer interaction (HCI) systems. Electroencephalogram (EEG) signals are the main source of emotion in our body. Recently, emotion recognition based on EEG signals have attracted many researchers and many methods were reported. Different types of features were extracted from EEG signals then different types of classifiers were applied to these features. In this paper, a deep learning method is proposed to recognize emotion from raw EEG signals. Long-Short Term Memory (LSTM) is used to learn features from EEG signals then the dense layer classifies these features into low/high arousal, valence, and liking. DEAP dataset is used to verify this method which gives an average accuracy of 85.65%, 85.45%, and 87.99% with arousal, valence, and liking classes, respectively. The proposed method introduced high average accuracy in comparison with the traditional techniques.**

***Keywords*—Electroencephalogram; emotion; emotion recognition; deep learning; long-short term memory**

I. Introduction

Emotion is the most important component of being human, and very essential for everyday activities, such as the interaction between people, decision making, and learning. It eases the communication between people and makes it representative. It is important to detect and recognize the emotion in computer systems which people interact with, to enhance the communication between users and machines. Moreover, we need to know the current state of the user to enhance the accuracy and throughput of the system.

In order to make the computer understand and recognize emotion, we need to understand the sources of them in our body. Emotion could be expressed verbally like some known words or non-verbally like the tone of voice, facial expression and physiological changes in our nervous system. Voice and facial expression are not reliable indicators of emotion because they can either be fake by the user or may not be produced as a result of a specific emotion.

The physiological signals are more accurate because the user cannot control it. Physiological changes are the main sources of emotion in our body. There are two types of physiological changes: one is related to Central Nervous System (CNS) and the other is related to Peripheral Nervous System (PNS). CNS consists of the brain and spinal cord. The brain is the center of everything in our body and every change in the electrical activity is translated into different actions and emotion. Electroencephalogram (EEG) is a measure of these electrical changes. EEG is defined as the electrical activity of an alternating type recorded from the scalp surface after being picked up by metal electrodes and conductive media [1].

Emotion recognition based EEG signals will provide an accurate emotion to use it in many fields. It can be used in automatic healthcare applications, helps autism to express their emotion and detect the state of the learner in E-learning system to develop an adaptive E-learning system.

In recent years, many emotion recognition approaches based on EEG signals have been proposed by many researchers. Koelstra [2] introduced a database for emotion analysis using physiological signals (DEAP). The main purpose of this database is to create music video recommendation system based on emotional state of the user. The music video clips are used to elicit different emotion. The physiological signals of 32 participants were recorded such as galvanic skin response, plethysmograph, skin temperature, breathing rate, Electromyogram, and EEG signals. 216 EEG features were extracted which are theta (4-8 Hz), slow alpha (8-10 Hz), alpha (8-12 Hz), beta (12-30 Hz), and gamma (30+ Hz) spectral power for 32 electrodes, and the difference between the spectral power of all the symmetrical pairs of electrodes on the right and left hemisphere. Fisher's linear discriminant was used for feature selection, then Gaussian naive Bayes used for classification with 3 different binary classification problems which are low/high arousal, low/high valence, and low/high liking.

Atkinson and Campos [3] proposed an EEG feature-based emotion recognition approach. DEAP [2] dataset was used to verify this approach. Statistical features were extracted which were the median, standard deviation, and kurtosis coefficient. Furthermore, band power of frequencies (theta (4-8 Hz), slow alpha (8-10 Hz), alpha (8-12 Hz), beta (12-30 Hz), gamma (30+ Hz)), Hjorth parameters (HP) and Fractal dimension (FD) were extracted for each channel. The minimum-Redundancy Maximum-Relevance (mRMR) was used to select a relevant set of extracted features. Then support vector machine (SVM) was used to classify features into low/high arousal and low/high valence classes.

Jadhav et al. [4] used EEG spectrogram image for emotion recognition. Gray-Level Co-occurrence Matrix (GLCM) features were extracted from EEG spectrogram image. DEAP dataset was used in this work to classify four emotions which are Happy, angry, relax, and sad. K-nearest neighbor was used for classification.

Chanel et al. [5] proposed a new approach for adapting game difficulty according to the current emotion of the player. EEG signals were recorded from 14 players playing a Tetris game at three different levels easy, medium, and hard which are related to boredom, engagement, and anxiety emotions, respectively. For each electrode, the energy of different frequency bands which are theta (4-8 Hz), alpha (8-12 Hz), and beta (12-30 Hz) was computed using Fourier Transform. Furthermore, EEG_W features were computed for all electrodes as shown in (1).

$$EEG_W = \log \frac{\sum_{i=1}^{N_e} \beta_i}{\sum_{i=1}^{N_e} \theta_i + \alpha_i} \tag{1}$$

Different feature selection methods were experienced with different classifiers. The best accuracy was 56% which was obtained by using analysis of variance (ANOVA) as feature selection method and Linear discriminant analysis (LDA) as a classifier.

Yoon and Chung [6] proposed a new methodology for emotion recognition from EEG signals. DEAP dataset was used to verify this method. Fast Fourier Transform analysis was used in feature extraction. Then, feature selection based on Pearson correlation coefficient was applied on extracted features. They proposed a probabilistic classifier based on Bayes theorem and a supervised learning using a perceptron convergence algorithm.

Naser and Saha [7] proposed a new method for emotion recognition from EEG signals. DEAP dataset was used to verify this method. Dual-tree complex wavelet packet transform (DT-CWPT) was used for feature extraction. Then redundant features were eliminated using Singular value decomposition (SVD), QR factorization with column pivoting (QRcp), and F-ratio. Support vector machine was used for classification.

Liu et al. [8] proposed a new method for emotion recognition from EEG signals using DEAP dataset. Twelve different features were extracted from the time domain, frequency domain, time-frequency domain, and multi-electrode features. Minimum Redundancy Maximum Relevance (mRMR) was used for feature selection. K-Nearest Neighbour (KNN) and Random Forest (RF) were used for classification.

Bhagwat and Paithane [9] proposed a new method to classify four emotions which are happy, angry, cry, and sad. Wavelet Transform (WT) was used to extract features from raw EEG signals. Hidden Markov Model (HMM) was used for classification.

Hatamikia and Nasrabadi [10] proposed a new method for emotion recognition from EEG signals. Four feature extraction methods were used which are Approximate Entropy, Spectral Entropy, Katz's fractal dimension, and Petrosian's fractal dimension. In order to select the most informative features; two-stage feature selection method based on Dunn index and Sequential forward feature selection algorithm were used. Self-Organization Map (SOM) was used to classify emotions.

In short, in the previously presented work, researchers proposed various methods to extract different features from raw EEG signals. Different types of classifiers were applied to extracted features to recognize emotion. In order to improve the accuracy of emotion recognition system, In this paper, a new method is proposed to recognize emotion from raw EEG signals directly by using an end-to-end deep learning approach. The proposed method improves the accuracy as discussed in Section V.

The rest of the paper is organized as follows: in Section II DEAP dataset is described. Long Short-Term Memory Recurrent Neural Network (LSTM-RRN) is described in Section III. The proposed method is presented in Section IV. Results are shown in Section V. The whole paper is concluded in Section VI.

II. DATASET

DEAP dataset was recorded in order to create an adaptive music video recommendation system based on the current state of the user. Physiological signals were recorded from 32 healthy participants aged between 19 and 37 (with mean age 26.9 years). Each participant watched a one-minute long music video. After each trial/video, each participant performs self-assessment of their level of arousal, valence, like/dislike, and dominance. For 22 participants of the 32 participants, the frontal face video was also recorded. EEG and peripheral signals were recorded at a sampling rate of 512 Hz. Their EEG data were downsampled to 128 Hz, then, averaged to the common reference, after that, eye artifacts were removed, and a high-pass filter was applied. Also, the Peripheral signals were downsampled to 128 Hz.

Each participant's file contains two arrays as described in Table I.

TABLE I. DEAP ARRAYS OF EACH PARTICIPANT

Array Name	Array shape	Array contents
data	$40 \times 40 \times 8064$	video/trail $\times$ channel $\times$ data
labels	40×4	video/trail $\times$ label (valence,arousal,dominance,liking)

As mentioned in Table I each participant have an array of 40 watched videos $\times$ 40 (EEG+peripheral) channels $\times$ 8064 reading. In this paper, only EEG signals are used. The 8064 reading per EEG channels divided into 12 segments which each is 5 seconds long of approximately 21504 reading.

III. LONG SHORT TERM MEMORY (LSTMS)

Long Short-Term Memory Networks (LSTMs) are special kind of Recurrent neural network (RNN). It was introduced by Hochreiter and Schmidhuber in 1997 [11] in order to overcome the problem of long-term dependency in RNN. Long sequences can be difficult to learn from standard RNN because it's trained by back-propagation through time (BPTT) and that causes the problem of vanishing/exploding gradient. To solve this, the RNN cell is replaced by a gated cell, like LSTMs cell. Figure 1 shows the basic architecture of LSTMs cell.

These gates control which information must be remembered in memory and which are not. The memory added to LSTMs cell makes it able to remembers previous steps. The key to LSTMs is the cell state (the horizontal line on the top of figure 1 (C_t)). LSTM has the ability to remove or add

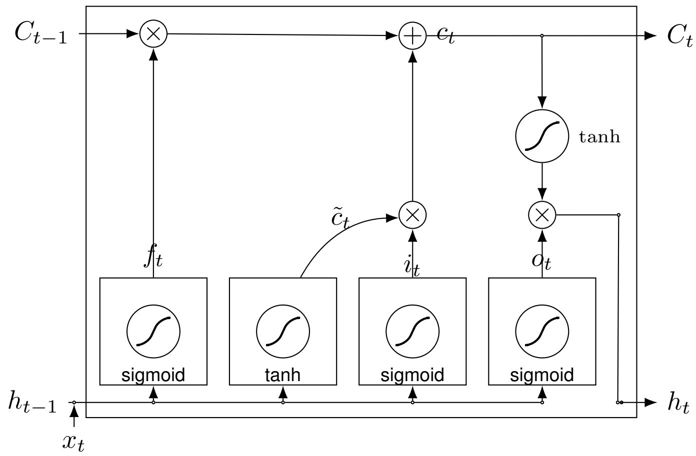

Fig. 1. LSTM cell architecture.

information to the cell state by using three gates. The first gate is a forget gate to decide what information to throw away from the cell state, this decision made by a sigmoid layer

$$f_t = \sigma(W_f \cdot [h_{t-1}, x_t] + b_f) \tag{2}$$

The second gate is an input gate which consists of sigmoid layer to decide which values will be updated, and tanh layer which creates a vector of new updated values as described in (3) and (4)

$$i_t = \sigma(W_i \cdot [h_{t-1}, x_t] + b_i) \tag{3}$$

$$\tilde{C}_t = \tanh(W_c \cdot [h_{t-1}, x_t] + b_c) \tag{4}$$

Then the cell state updated from equations 2, 3, and 4 by

$$C_t = f_t * C_{t-1} + i_t * \tilde{C}_t \tag{5}$$

Finally, the output of the current state will be calculated based on the updated cell state and a sigmoid layer which decides what parts of the cell state will be the final output as described in equations 6 and 7

$$o_t = \sigma(W_o \cdot [h_{t-1}, x_t] + b_o) \tag{6}$$

$$h_t = o_t * \tanh(C_t) \tag{7}$$

where σ is sigmoid activation function which squashes numbers into the range (0,1), $\tanh$ is hyperbolic tangent activation function which squashes numbers into the range(-1,1), W_f, W_i, W_c, W_o are the weight matrices, x_t is the input vector, h_{t-1} denote the past hidden state and b_f, b_i, b_c, b_o are bias vectors.

IV. Proposed Method

In this paper, end-to-end deep learning neural network is applied to raw EEG signals of 32 participants who watched the 40 videos, in order to recognize the emotion elicited from these videos. Each video segmented into 12 segments with a length of 5 seconds. DEAP [2] dataset was used to verify the algorithm in this work. As mentioned in Section II each participant has an array of data and array of labels. label array represents the ratings of each video performed by each participant. The ratings represent their levels of arousal, valence, and liking in continuous scale ranged from 1 to 9. Three different classification problems were posed: low/high arousal, low/high valence, and low/high liking. Since there are two levels only per each classification problem, then the continuous rating range per class is thresholded in the middle such that if the rating is greater than or equal to five then the video/trail belongs to high class otherwise, it belongs to the low class.

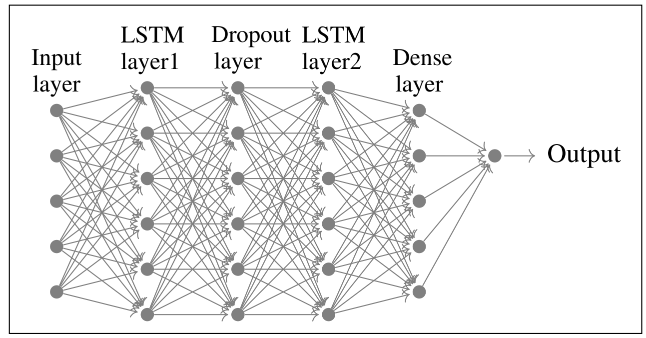

Fig. 2. Neural network model.

Fig. 2 shows the proposed deep learning neural network model. It consists of fully connected two LSTM layer, dropout layer, and dense layer. The dropout layer used to reduce the Overfitting by preventing units from co-adapting too much. The LSTM and dropout layers are used to learn features from raw EEG signals and the dense layer is used for classification.

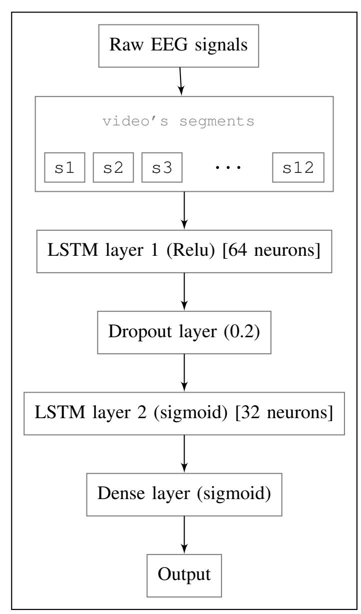

Fig. 3. Detailed proposed model.

Each participant data consists of 8064 readings for 32 EEG channels for each video. each video segmented into 12 segments with a length of 5 seconds. each segment consists of 672 readings for 32 EEG channels. The Deep learning model used in this paper consists of the input layer, the first sequence-to-sequence LSTM layer, a dropout layer with a probability of 0.2, a many-to-one LSTM layer, and a dense layer for binary classification as shown in figure 3. The first hidden layer contains 64 neurons and used Relu as an activation function.

$$ReLU(x) = \max(0, x) \tag{8}$$

The second LSTM layer contains 32 neurons and used sigmoid activation function. The dense layer used sigmoid activation function. The total number of parameters in this model is 5534113.

The model is trained on 75% of the videos using 4 fold cross-validation and tested on 25% of them. Thirty epochs used for each cross-validation iteration. RMSprop optimizer used in training process with 0.001 learning rate. Keras [12] library with TensorFlow backend is used to implement the proposed deep learning method.

V. Results

DEAP [2] dataset is used to verify the algorithm proposed in this paper. As described in Section II, EEG signals are recorded from 32 participants. The algorithm is applied to each participant separately and the accuracy is calculated. therefore, the average accuracy over all participants is calculated for three classification problems which are low/high arousal, valence, and liking.

The results provided by the proposed method has been compared with four different methods which all used DEAP dataset as shown in Table II. The proposed method achieves the higher accuracy for all classes as shown in Fig. 4.

TABLE II. The Average Accuracy

	Arousal	Valence	liking
Koelstra et al. [2]	0.620	0.567	0.554
Atkinson and Campos [3]	0.7306	0.7341	-
Yoon and Chung [6]	0.701	0.709	-
Naser and Saha [7]	0.662	0.643	0.702
proposed method	**0.8565**	**0.8545**	**0.8799**

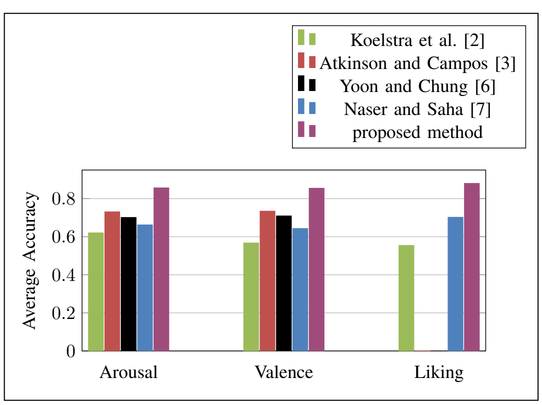

Fig. 4. Average accuracy.

VI. Conclusion

This paper presents an end-to-end deep learning neural networks method to recognize emotion from raw EEG signals. LSTM-RNN is used to learn features from EEG signals then the dense layer is used for classification. Results show that the proposed method is a very promising choice for emotion recognition, because of its powerful ability to learn features from raw data directly. It achieves high average accuracy over participants compared to the traditional feature extraction techniques.

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Framework for Managing Uncertain Distributed Categorical Data

Adel Benaissa, Mustapha Yahmi, Yassine Jamil
Université Paris Cité Sorbonne
Laboratoire informatique Paris Descartes
45, Rue des saints pères
Paris, France

***Abstract*—In recent years, data has become uncertain due to the flourishing advanced technologies that participate continuously and increasingly in producing large amounts of incomplete data. Often, many modern applications where uncertainty occurs are distributed in nature, e.g., distributed sensor networks, information extraction, data integration, social network, etc. Consequently, even though the data uncertainty has been studied in the past for centralized behavior, it is still a challenging issue to manage uncertainty over the data *in situ*. In this paper, we propose a framework to managing uncertain categorical data over distributed environments that is built upon a hierarchical indexing technique based on inverted index, and a distributed algorithm to efficiently process queries on uncertain data in distributed environment. Leveraging this indexing technique, we address two kinds of queries on the distributed uncertain databases 1) a distributed probabilistic thresholds query, where its answers satisfy the probabilistic threshold requirement; and 2) a distributed top-k-queries, optimizing, the transfer of the tuples from the distributed sources to the coordinator site and the time treatment. Extensive experiments are conducted to verify the effectiveness and efficiency of the proposed method in terms of communication costs and response time.**

***Keywords*—Distributed uncertain data; Top-k query; threshold query; indexing; categorical data**

I. Introduction

In recent years, data has become uncertain due to the flourishing of advanced technologies that participate continuously and increasingly in producing large amounts of incomplete data, data with missing values and uncertain data. When we talk about these types of data, some questions that come to mind are: 1) What are uncertain, imprecise and incomplete data? 2) How can we represent these data? 3) What is the difference between them? 4) How can we manage these types of data? 5) Can we use the traditional relational database management systems to store and request these data?. Therefore, Researchers of the database community have been asking these questions since the early 1980's. In fact, managing uncertain data has seen a revival in recent years due to new methods and the emergence of applications that produce this type of data. This is what prompts many challenges in terms of modeling, storing, indexing and querying uncertain data. Thus, many efforts have been devoted to studying uncertain databases. These efforts yield different approaches and algorithms for modeling and representing uncertain data [1–3], indexing techniques and query processing over uncertain data [3–9].

Over the last decade, many cases where uncertainty arises have been distributed in nature, e.g. distributed sensor networks and multiple data sources for information integration [10–12]. Unfortunately, existing techniques that include indexing and query processing over uncertain data were mainly proposed in centralized environments and are not adaptable to distributed environments. As a result, it is still challenging to efficiently process queries over distributed uncertain data. Notable exceptions include recent work on indexing and query processing of distributed uncertain data [10–13]. These works have only considered top-k queries on uncertain real-valued attributes. Distributed top-k query processing focuses on reducing communication cost while providing high quality answers. However, in many domains, data records are composed of a set of descriptive attributes many of which are neither numeric nor inherently ordered in any way. In this paper, we address the problem of indexing and query processing on uncertain categorical data in distributed environments. We propose an original approach that efficiently answers queries on distributed uncertain data with minimum communication and processing costs.

Example 1.1: Let us consider that $Farm$ is a relation that stores bovine records of breeders and veterinary surgeons as it is explained in the motivating example of the general introduction. The Relation $Farm$ is specified by the schema $Farm(T_{id}, weight, illness)$ where the *illness* attribute specifies the illnesses that can affect a cow. *Illness* attribute is an uncertain one that takes its values from the categorical domain $\{mc, fa, nc, fs\}$ where *mc* means *mad cow*, *fa* means *fever accurate*, *nc* means *normal cow*, *fs* means *fever simple*. Let R be a relation instance of $Farm$. In Fig. 1, the relations R_1, R_2, R_3 and R_4 are the horizontal partitions of R on S_1, S_2, S_3 and S_4 distributed sites respectively. The first tuple in R_1 specifies that the cow with the identifier T_1 has a weight 700 kg and that its possible illness maybe *acute fever (fa)* with the probability 0.7 or maybe *simple fever (fs)* with the probability 0.3. The veterinary surgeons are interested in locating which farm is affected by a disease in order to begin preventive measures.

From the previous Example 1.1, two interesting queries for the breeders and insurers are as follows:

$Q1$: *Find the cows affected by an accurate Fever with a probability above 0.5*;

$Q2$: *Find the two cows affected by an accurate fever in all the farms*.

The query $Q1$ aims to identify the tuples where the illness attribute has the value *fa* and The query $Q2$ aims to return the first 2 tuples with the highest probability, where the

T_{id}	Weight	Illness
T_1	700	$\{(fa, 0.7); fs(0.3)\}$
T_2	710	$\{(fa, 0.9); fs(0.1)\}$
T_3	790	$\{(nc, 1)\}$
T_4	725	$\{(nc, 0.9); (fs, 0.1)\}$

(a) R_1

T_{id}	Weight	Illness
T_5	700	$\{(fa, 0.2); fs(0.8)\}$
T_6	710	$\{(fa, 0.9); fs(0.1)\}$
T_7	790	$\{(nc, 0.85); (fs, 0.15)\}$
T_8	725	$\{(nc, 0.9); (fs, 0.1)\}$

(b) R_2

T_{id}	Weight	Illness
T_9	749	$\{(mc, 0.8); nc(0.2)\}$
T_{10}	645	$\{(mc, 1)\}$
T_{11}	801	$\{(nc, 0.7); (mc, 0.3)\}$
T_{12}	799	$\{(nc, 0.5); (mc, 0.5)\}$

(c) R_3

T_{id}	Weight	Illness
T_{13}	711	$\{(mc, 0.18); nc(0.82)\}$
T_{14}	745	$\{(nc, 0.9); (mc, 0.1)\}$
T_{15}	901	$\{(nc, 0.85); (mc, 0.15)\}$
T_{16}	799	$\{(nc, 0.95); (mc, 0.05)\}$

(d) R_4

Fig. 1. Example of distributed uncertain relation R.

illness attribute has the value *nc*. The two queries $Q1$ and $Q2$ are distributed probabilistic threshold and distributed top-k queries, respectively .

A straightforward and naive approach to answer such a query is to answer the above queries is to forward them to all the sites so that local treatment and processing will be done on each site locally. Then, each site send its results to the coordinator site. Finally the query site merges the tuples received from all sites and computes the final result. The drawbacks of this approach is that all sites are asked even when their tuples are not involved in the final response. Also, transferring a large number of tuples consumes bandwidth in the network and takes time to process. Furthermore, this approach does not scale with number of distributed sites. Hence, In order to address these drawbaks, we propose an approach that use a *Local Uncertain Index* (***LUI***) for uncertain data on each local site, while a *Global Uncertain Index* (***GUI***) is used to summarizing the local indexes. The local and global uncertain indexes are inverted-index based structures. We show that these structures support a broad range of probabilistic queries over uncertain data, including distributed uncertain threshold and top-k queries. Specifically, we propose `DUTh` and `DUTk`, two distributed algorithms for processing probabilistic threshold and top-k queries on distributed uncertain data. The main contributions of this paper are as follows:

- We propose a distributed indexing of distributed uncertain categorical data based on a two-level hierarchical index: a local index ***LUI*** on each site [7] and a top-level global index on a coordinator site (***query site***). The global index(***GUI***) summarizes local indexes and determines which ones should be accessed.
- We propose two distributed algorithms `DUTh` and `DUTk` to respectively answer threshold and top-k queries. Our proposed algorithms use the proposed indexes LUI and GUI to perform distributed pruning and allow minimum communication and processing costs.
- We conduct an extensive experimental study to evaluate our proposed framework over syntactic data. The results of the study show the efficiency of our two proposed algorithms and indexing techniques.

The rest of this paper is organized as follows: Related work is presented in Section II. Then, Section III presents the problem definition. In Section IV, we present an overview of our proposed framework. Section V presents our distributed indexing technique. In Section VI, we describe query processing using the distributed index. We report a performance evaluation of our proposed framework in Section VII and finally we conclude the chapter in Section VIII.

II. Related Work

With the advent of the Internet and network technology [14], there is an important emergence and unprecedented flourishing of real world applications and devices that participated to produce large amounts of uncertain data daily. e.g. data collected from sensor networks [15], information extraction from the web [16, 17], data integration[18, 19], data cleaning [20–25], social networks [26, 27], radio frequency identification RFID [7]. Due to various reasons that differ from one application to another, the uncertainty is inherent in such applications. With the emergency of these applications, considerable research efforts have been made in into the field of managing uncertain data [6]. Existing work in this area provides new models for uncertain data, prototype implementations, specific indexing techniques and efficient query processing algorithms.

Indexing uncertain data was extensively studied in the literature of centralized uncertain databases. Many approaches and a variety of indexing techniques were proposed in this field. However, these are not suitable for distributed uncertain data. To the best of our knowledge, there is only the work in [12] that proposed indexing uncertain data, presented as moving objects over a peer to peer (P2P) environment based on Quad-Tree indexes structures. In our work, we aim to propose an original indexing technique for uncertain data in general distributed environments and not specifically P2P environments.

As the same, many query processing techniques on distributed certain data have been studied with particular interest in top-k queries [5, 15]. However, these techniques are not adaptable to uncertain distributed environments. As a result, it is still challenging issue to efficiently process queries on distributed uncertain data. Thus, we aim to study query processing over uncertain distributed data based on efficient index structures.

Most existing work on top-k query processing in distributed environments performs with several rounds of communication between the query site and the other distributed sites. As a result, it is still challenging to efficiently process top-k queries in a minimum communication rounds between sites. In our work, we seek to reduce the communication cost of query processing in distributed environments and reduce it to one round of communication, in addition to dealing with uncertainty.

In the literature, the majority of works considered top-k queries on uncertain real-valued data. However, in many domains, data records are composed of a set of descriptive attributes, many of which are neither numeric nor inherently ordered in any way. Thus, we focus on indexing and querying distributed uncertain data presented as qualitative (or categorical) data.

III. Problem Definition

In this section, we describe the data model and query classes which we consider in our work. Then, we define the problem of query processing over uncertain categorical data on distributed environments.

A. Data Model

Uncertainty can be identified both at the tuple level [1, 3] and the attribute level [2]. In this work, we consider the attribute-level uncertainty model. The uncertain data in our work is modelled as a probabilistic database horizontally distributed over a set of sites $\mathcal{S} = \{S_1, S_2, ..., S_m\}$. A database consists of a set of relations R partitioned into (R_1,..., R_m) such that $R = \bigcup_{i \in [1,m]} R_i$ and $R_i \cap R_j = \emptyset$, for $i, j \in [1..m], i \neq j$. Consequently, each database on a local site S_i consists of a relation R_i, with n tuples each of which has uncertain attribute values. For the sake of simplicity and without loss of generality, we limit the discussion to relations with a single uncertain attribute. In our work, we focus on uncertain attributes that are drawn from categorical domains. Let $\mathcal{S}.a$ be a particular attribute in $\mathcal{S}$ which is uncertain. $\mathcal{S}.a$ takes values from the categorical domain D with cardinality $|D| = N$. For a traditional (certain) relation, the value of an attribute a for each tuple would be a single value in D. In the case of an uncertain relation, $t_k.a$ is a probability distribution over D instead of a single value. Let $D = \{d_1, d_2, ..., d_N\}$, then $t_k.a$ is given by the probability distribution $Pr(t_k.a = d_i)$ for $i \in \{1, ..., N\}$. We illustrate our uncertainty model with the following example:

B. Basic Queries on Uncertain Data

We specifically examine two types of queries: distributed uncertain query threshold and top-k queries. They are defined below:

Distributed Uncertain Threshold Query (`DUTh`): Threshold queries can be used in different settings [28]. In the literature related to databases, there has been much interest in studying such queries [29]. Generally, most of these work said that the goal of this type of query is to detect all tuples (or objects) whose likelihood (or score) exceeds a given threshold. In our work, we defined a distributed threshold query as follows[1]:

Definition 3.1: Given a set of distributed uncertain relations $\mathcal{S} = \bigcup_{i \in [1,m]} S_i$, `DUTh` returns a set of tuples $t_k \in S_i$ such that $Pr(t_k.a = d_i) > \tau$, where τ is a probability threshold and $t_k.a$ is a probability distribution over D where $D = \{d_1, d_2, ..., d_N\}$.

Example 3.1: From the previous Example 1.1, an interesting query for the breeders and insurers is as follows:

$Q1$: *Find the cows affected by an accurate Fever with a probability above 0.5*

The query $Q1$ is distributed probabilistic threshold queries that aim to identify the tuples where the illness attribute has the value *fa* with probability above 0.5 (cf. Fig. 1) respectively, from the whole distributed relation $\mathcal{S}$.

Distributed Uncertain Top-k Query (`DUTk`): A lot of effort has been devoted to studying top-k query in the uncertain database [30]. The majority of these works considered two aspects for ranking (top-k) uncertain databases. These were the score and the likelihood of objects (or tuples). In our work, we consider only the likelihood attached to the tuples in the ranking process. Hence, the definition of the top-k query in our work is as follows:

Definition 3.2: Given a set of distributed uncertain relations $\mathcal{S} = \bigcup_{i \in [1,m]} S_i$, `DUTk` returns the k first tuples $t_k \in S_i$ with the highest probability among all distributed sites of $\mathcal{S}$.

Example 3.2: From the previous example 1.1, an interesting query for the breeders and insurers is as follows:

$Q2$: *Find the two cows affected by an accurate fever in all the farms*

The query $Q2$ is distributed probabilistic Top-k queries. The aim of query $Q2$, is to return the first 2 tuples with the highest probability, where the illness attribute has the value *fa*.

IV. Proposed Framework

Having presented the uncertain model and the query classes that we aim to process, let us now present, the main components of our framework. The principal aim of our approach is to efficiently answer queries on uncertain distributed data with minimum communication and processing costs. Our framework is performed in two main phases (Fig. 2):

Offline Phase

We propose a distributed indexing technique based on a two-level hierarchical index:

- ***Local uncertain indexes(LUI)*** : we build a local index at each local site. To do so, we adopt the inverted uncertain index structure proposed by Shin et al. [7].
- **Global uncertain index(GUI)**: This index summarizes the local indexes on the distributed environments.

[1] In our work, we do not use the family of threshold algorithms [28] for the reason that we treat queries with threshold probability in distributed environments in different contexts.

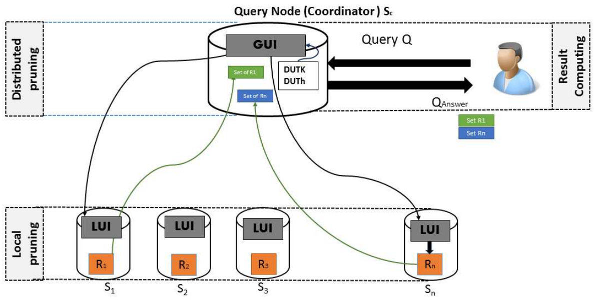

Fig. 2. Our proposed framework.

Its structure is the same as the local index structures LUI (Inverted list).

Online Phase

Using the local (LUI) and global uncertain indexes (GUI), we propose two distributed algorithms `DUTh` and `DUTk` to respectively answer distributed uncertain threshold and top-k queries. The main steps of the proposed algorithms are as follows:

- **`DUTh` (Distributed Uncertain Threshold Query)**: In this algorithm, only the sites whose tuples are involved in a final response are asked. `DUTh` performs the following main steps in one round of communication:
  - Distributed Pruning on the coordinator site.
  - Local pruning on each site.
  - Result computation on the coordinator site.
- **`DUTk` (Distributed Uncertain Top-k Query)** The main objective of this algorithm is to reduce the communication cost and time processing of the execution of the Top-k query processing. To do this, the top-k query will only be concerned with a subset from $\mathcal{S}$. The main steps of this algorithm are:
  - Distributed Pruning on the coordinator site.
  - Probability threshold tuning.
  - Local pruning and query ranking.
  - Distributed query ranking.

V. Distributed Uncertain Indexing

To index distributed uncertain data, we propose a two-level hierarchical index: a local index on each site as proposed in [7] and a top-level global index to determine which local indexes should be accessed. Hence, our indexing process is performed in two stages. In the first stage, each local site builds its local uncertain index. In the second stage, summaries from local indexes are merged to build a global index on a coordinator site where the query will be executed. In what follows we describe the main process used to build local and global uncertain indexes in detail.

A. Local Uncertain Index Structure

For the local uncertain index on each site we adopt the inverted index based structure proposed in [7]. The main build of this index is as follows:

Each value d_i of an uncertain attribute a is stored in the list of the inverted index, which consists of a set of pairs including the T_{id} tuple of the local relation R_i and the probability of $d_i.a$ attached to T_{id}. Therefore, the component of the list of a given $d_i \in D$ is a pair of (t_{id}, P_i). This list is organized in decreasing order. In practice, such a list is organized in the memory with a dynamic structure such as B+ tree. The main advantage of the local indexing is that most parts of the query processing can be performed by the site containing the required index data. The site responsible for solving the query is only required to broadcast the query to the coordinator site, which then combines the returned results.

Example 5.1: Returning to Example 1.1 of the uncertain distributed database R in Fig. 1. The local uncertain index LUI of R_1 (the local relation of R on S_1) is depicted in Fig. 3. It is built on the *illness* uncertain attribute. Notice that each entry of LUI corresponds to a value from the categorical domain of *illnesses*: $\{mc, fs, fa, nc\}$. For each of those values, a set of pairs is stored. For instance, the $\boldsymbol{nc}$ value is associated with the following pairs $(t_3, 1)$ and $(t_4, 0.9)$. The pair $(t_3, 1)$ specifies that the tuple with the t_3 identifier includes the value $\boldsymbol{nc}$ with the probability 1 in its *illness* uncertain attribute.

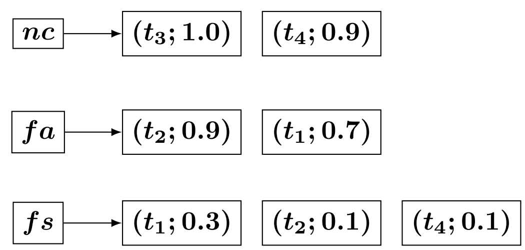

Fig. 3. Local inverted index of R_1.

B. Global Uncertain Index Structure

Now, we describe the structure of the global uncertain index which we refer to as GUI. The GUI determines which local index(es) should be accessed. Hence, GUI should be stored in the coordinator site.

```
input : D = {d1, d2..., dn}; S = {S1, S2..., Sn};
output: GUI

for each site ∈ S do
    Goes through the index LUI
    for each d ∈ {D ∧ LUI} do
        P_max ← maximal probability of d in LUI
        Ld ← (S, P_max))
    end
end

for each d ∈ D do
    organize ld as inverted list in decreasing order
end
return(GUI)
```

Algorithm 1: Global Index (GUI) Construction

Given a distributed relation R on $\mathcal{S}$, GUI is an inverted index based structure on the uncertain attribute a of R. It summarizes information of local indexes LUIs. More specifically, it stores the sites of each LUI. As for the local indexes, entries in

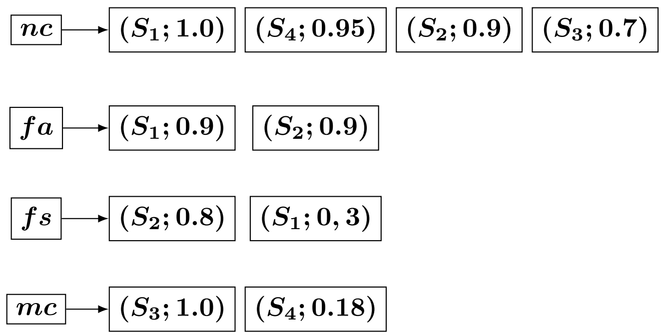

Fig. 4. Global inverted index (GUI).

a GUI correspond to the categorical domain values of a, i.e. $\{d_1, d_2..., d_n\}$. For each entry d_j, GUI collects information from the local indexes as shown below:

- Given a LUI stored on a local site S_i, for each entry d of LUI, GUI stores one pair (S_i, P_{max}) where $S_i \in \mathcal{S}$ and $P_{max}(R.a = d)$ is the maximum probability over the set of pairs (t_{id}, P_{max}) associated with d on the LUI of site S_i.
- To complete the list of pairs for each entry d_j in the GUI, all the LUI's are explored to obtain the corresponding pair for d_j as performed above. Once the list is completed, the pairs are ordered in decreasing order of their probabilities.

Algorithm 1 depicts the main steps of creating the GUI.

Example 5.2: Returning to Example 1.1 of the distributed database R in Fig. 1. The global uncertain index of our distributed environments is depicted in Fig. 4. In our distributed environment we have four values of the domain $D = \{nc, mc, da, fs\}$, For each of those values, a set of pairs is stored. Hence each value from domain D has an inverted list. For instance, the $\boldsymbol{fa}$ value is associated with the following pairs: $(S_1, 0.9)$ and $(S_2, 0.9)$. The pair $(S_2, 0.9)$ specifies that the illness $\boldsymbol{fa}$ is located in site S_2 with maximal probability 0.9. The Inverted list of $\boldsymbol{fa}$ indicates that this illness is only located within site S_1 and site S_2.

In what follows, we will discuss how to provide two kinds of queries on uncertain distributed sites using the proposed index structures.

VI. Distributed Uncertain Query Processing

In our uncertain distributed environment, the query can be initiated by the coordinator site, also called query site (S_c). The naive approach[2] to processing a distributed query requires transferring an excessive amount of data and processing the distributed query at each site. Instead, we present two algorithms `DUTh` and `DUTk` which improve the overall performance by reducing both the processing and communication cost of the threshold and top-k queries, respectively.

[2] We will call this approach `NAIV` in our experiments.

A. Distributed Uncertain Threshold Algorithm

The Distributed Uncertain Threshold Algorithm, referred to as `DUTk`, is depicted in Algorithm 2. The aim of our algorithm is to reduce the communication cost by pruning the sites that are not concerned by the query. Let us consider an uncertain

input : Query Q,Index GUI ,Threshold:τ
output: $DUTh_{response}()$
$DUTh_{response}() = \{\};$
$Q_{answer} = \{\}$
Execute query Q in coordinator site;
Goes through the index GUI;
for *each S_i in index GUI* **do**
  if $p_{max} > \tau$ **then**
    Execute query Q ;
    $Q_{answer} \leftarrow$ Answer of Q
  end
  $DUTh_{response}() \leftarrow DUTh_{response}() \cup Q_{answer}$
end
return($DUTh_{response}()$)

Algorithm 2: The `DUTh` Algorithm

database R distributed over a set of site $\mathcal{S} = \{S_1, S_2, ..., S_m\}$ and query Q on $\mathcal{S}$. Note that the query Q will be initiated in the coordinator site with a given threshold probability (τ). The main steps of the `DUTh` algorithm execution are as follows:

- The query Q will be executed in the coordinator site $S_c \in \mathcal{S}$. The first step of `DUTh`, is to go through the global index (GUI) and visit the inverted list of associated value driven from the domain of categorical data initiated in the query Q.
- In this step, we get only the list of sites which have maximal probability greater than the defined threshold ($p_{max} > \tau$). All sites that cannot satisfy this condition will not be concerned by the query Q and will be pruned.
- The query will be sent to the concerned sites where it will be executed locally. Notice, that in each concerned site, pruning is performed locally.
- Each site forwards its results to the coordinator site, which will merge all the received results.

Example 6.1: We illustrate the main steps of `DUTh` by considering the query Q_1 from Example 3.1 that we will execute on the farms data depicted in Example 1.1 and Fig. 1:

$Q_1 : Select{*}from\ \mathcal{S}\ hereW\ illness =' fa'$ And $P > 0.5$

We suppose that we would have all cows that are affected by fa illness with probability ($p > 0.5$).

- The query Q_1 is executed in the coordinator site. In the first step of our `DUTh`, the GUI will be visited to obtain a list of sites(farms) where fa illness is present.
- Then, we visit the inverted list of fa. All sites that had maximal probability of illness q above $p < 0.5$ will be pruned. Consequently, in our case the query Q_1 will be concerned with farm S_1 and S_2.

- Next, we send the query Q_1 to S_1 and S_2 with threshold probability $\tau > 0.5$
- In the farms S_1 and S_2 the query Q will be executed and local pruning will be performed in each sites (R_1 and R_2).
- Only tuples with probability attached to value fa above 0.5 will be returned to the coordinator site S_c as presented in Table I.

TABLE I. RESULTS OF DUTH QUERY Q_1.

$R_i.T_{id}$	weight	illness
$R_1.T_1$	700	(fa,0.7)
$R_1.T_2$	710	(fa,0.9)
$R_2.T_6$	710	(da,0.9)

B. Distributed Uncertain Top-k Algorithm

Given an uncertain relation $R = \bigcup_{i\in[1,n]} R_i$ distributed on $\mathcal{S} = \{S_1, S_2, ..., S_n\}$ where R_i is located on S_i. Each S_i stores a local index LUI and a coordinator site S_c stores a global index GUI. Given a top-k query Q issued from S_c, the algorithm `DUTk` will efficiently and effectively answer Q. We consider the following query Q on the distributed relation R. The class of queries we treat are obviously those with an uncertain attribute in the where-clause. The main steps of the execution of `DUTk` are as follows:

```
input : Query Q,Index GUI ,DUTh, k
output: DUTk_response()
DUTk_response() = {};
Execute query Q in coordinator site;
crossing the index GUI;
Li ← list of site from GUI
for each S_i in liste Li do
    explore LUI;
    Lp_min ← get the probability of k_th of site from
      Local index;
end
τ ← Max of Lp_min
//Execute Threshold algorithm DUTh(τ)
Global_response← Duth(τ)
//Merge and Rank the results, then choose the top-k
  response
DUTk_response() ← Order(Global_response(limitk))
return(DUTk_response())
```

Algorithm 3: `DUTk` Query Algorithm

- **Distributed pruning:** On the coordinator S_c where Q is executed, the algorithm explores the global index GUI to find the uncertain attribute value of the where-clause, and then obtain the distributed sites in the corresponding list of that value. Let $S_Q = \{S_1, S_2, ..., S_h\}$ where $h \leq m$, is the list of the distributed sites where Q should be executed. The coordinator site S_c broadcasts the query Q to those sites. Notice that the GUI allows distributed pruning, i.e. only sites where Q should be executed are considered and the others are pruned. The main advantages of this pruning is reducing the query processing time and cost.
- **Probability threshold tuning:** On each site S_i in S_Q from the previous step, the algorithm explores its local indexes LUI. The aim of this step is to search the k^{th} probability P_i (i.e. the maximal probability in the LUI inverted list) from each selected site. Then, this probability value is sent to the query node where a threshold list Th_{List} stores all the probability values sent by the distributed sites. The maximal probability, $\tau = Max_{i\in[1,m]} P_i$ (maximal probability of the list (Th_{List}), is considered as the new probability threshold, then a new pruning is performed from the global index GUI according to τ. Indeed, for each pair (S_i, P_{max}) from the GUI inverted list, if $P_{max} \leq \tau$, then the corresponding site S_i is pruned. The result of this step is a new list S_{Q_τ} of distributed sites where Q should be executed where $S_{Q_\tau} = \{S_1, S_2, ..., S_l\}$ where $l \leq h \leq m$. Consequently, the coordinator site S_c sends the query Q to the sites in S_{Q_τ}.
- **Local query ranking:** On each site S_i in S_{Q_τ}, the algorithm executes Q. It explores each local index LUI and obtains the tuples from the corresponding inverted list of the uncertain attribute value. Each node ranks its own tuples in decreasing probability order, stopping once no more tuples are likely to satisfy k. Then the ranked k^{th} tuples are sent to the coordinator site.
- **Distributed query ranking:** On the coordinator site, the algorithm computes the final query result. Another ranking is performed on the whole top-k tuples of each site.

Example 6.2: Returning again to Example 1.1, we illustrate the main steps of `DUTk` using the distributed environments presented in Fig. 1. Let us consider the query Q_2 of Example 3.2 that we can rewrite as follows:

Q_2: Find the two cows affected by an accurate fever (fa) in all the farms.

Let us show the execution of the example step by step:

- **Distributed pruning:** First, the GUI is explored to find the value fa of the uncertain attribute $illness$. Only the farms S_1 and S_2 are concerned by the query Q, because the value fa is present in these farms. The farm S_3 and S_4 will not be concerned by query Q_2 for the reason that value fa does not exist in these farms, so distributed pruning is first conducted in this step. As presented in Fig. 4, the GUI will contain the highest probabilities for each node, that is $max(S_1) = 0.9$, $max(S_2) = 0.9$,
- **Probability threshold tuning:** Second, the query site sends the query to the concerned farms S_1 and S_2. The aim is to get the 2^{nd} ($k = 2$) probability value fa after consulting their LUIs. Next, the farms S_1 and S_2 send the values of the 2^{nd} probability to the query site(($P_{2^{nd} of S_1} = 0.7$) and ($P_{2^{th} of S_2} = 0.2$)), which will define the maximal received value ($P_{max} = 0.7$) from S_1 as the new threshold probability. Then, given this threshold probability $\tau = 0.7$ the GUI will be

visited again and only the farm S_1 will be concerned by the query Q_2, S_2 will be pruned.

- **Locally query ranking:** Third, S_1 and S_2 will process the query locally and send the tuples that satisfy the threshold $\tau = 0.7$ to the query site. In this step only t_1,t_2 from S_1 and t_6 from S_2 will be retained.
- **Distributed query ranking:** Fourth, the query site will rank the received tuples in decreasing order of their probability and will finally choose the first two tuples as the result of top-2 of the query Q_2 (cf. Table II).

TABLE II. RESULT OF DUTK QUERY Q_2

$R_i.T_{id}$	Weight	Illness
$R_1.T_1$	700	(fa,0.9)
$R_2.T_6$	710	(fa,0.9)

From these steps, we have the following Lemma:

The DUTk algorithm effectively provides an effective top-k tuples with minimum cost communication and reduces the transferring of tuples between the coordinator site and the other sites. It executes the process in two rounds of communications between the query site and the other sites.

VII. EXPERIMENTAL STUDY

We experimentally evaluate the performance of our proposed algorithms DUTh and DUTk. We study the effect of the different parameters for both of the proposed algorithms and we compare their results with the NAIV approach to show the efficiency of the pruning phase.

We conduct an extensive experiment on a synthetic data sets. In particular, we have generated uncertain database *Farm* with three attributes (Fig. 1). The uncertain attribute *Illness* has 60 possible domain values ($|D| = 60$). The data sets follow two different distributions 1) a *pairwise* distribution where the probabilities for an illness are chosen randomly from [0,1]; and 2) a *Zipf* distribution over probabilities with the default skewness 1.2.

Next, we distributed the database horizontally over 50 sites where each site contains more than 230 000 tuples. To better show the performance of our algorithms and the efficiency of their pruning phases, we ensure that some categorical values do not appear in all sites. For this, we ensure that the distribution of the maximal probabilities of these categorical values are different in each site and their probabilities are in the range [0.1, 1].

We implemented DUTh,DUTk and NAIV in R and C# and tested them using a simulated distributed environment where each node has an Intel Core TM processor CPU 3.40 GHZ with 8 GO RAM. We measure the total communication cost in terms of number of transferred tuples. Then, we measure the response time as the time elapsed between sending the query from the query site and receiving all the responses in the query site. Each experiment is repeated 10 times in order to calculate an average time.

Table III shows the experimental setting.

TABLE III. EXPERIMENTAL SETTING

Symbol	Meaning	Range
m	number of nodes	$\{10, 20, 30, 40, 50\}$
k	size of top-k	$[10, 100]$ and $[100.1000]$
τ	threshold value	$[0, 1]$ and $[0.91, 1]$
N	size of database on each node	above 230000 tuples

A. *Efficiency of* DUTh

In this subsection, we show the efficiency of the proposed DUTh algorithm. In particular, we compare the DUTh algorithm with the NAIV algorithm. We conducted experiments on the two types of data sets and we consider the response time of DUTh compared with the naive algorithm (NAIV) that sends the query Q to all nodes.

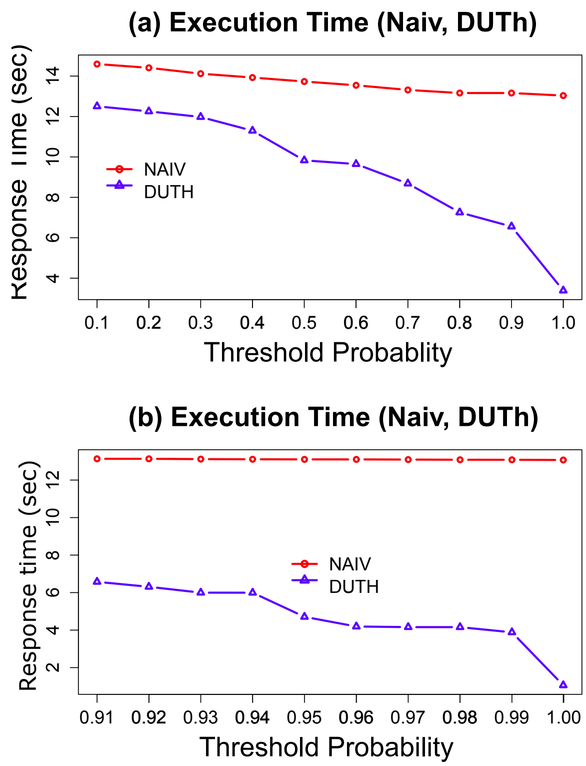

Fig. 5. Efficiency of DUTh with pairwise distribution by varying τ.

In these experiments, we varied the value of threshold τ (Table III). In Fig. 5(a) and 6(b), the threshold τ is in the range $[0.1, 1]$. For Fig. 6(b) and 5(b), it is in the range $[0.9, 1]$ with varying step 0.01. We observe that execution time for the DUTh algorithm decreases with the increase of the value of τ. For the highest value $\tau = 1$, the total response time is about 1.65 sec for DUTh and 13.79 sec for NAIV.

We note that the difference between the response time of DUTh and NAIV is due to the fact that the number of sites pruned are more important when the threshold probability is greater. When a threshold probability increases the number of pruned sites increases as well for the two data distributions.

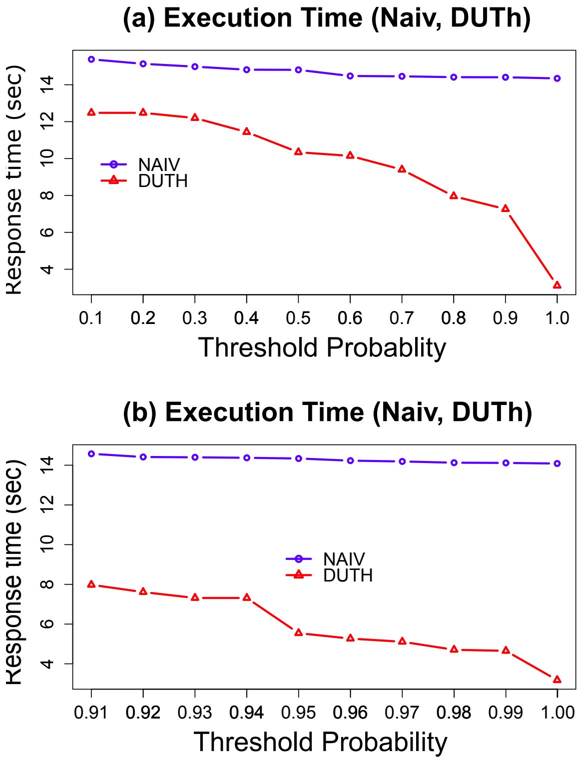

Fig. 6. Efficiency of `DUTh` with Zipf distribution by varying τ.

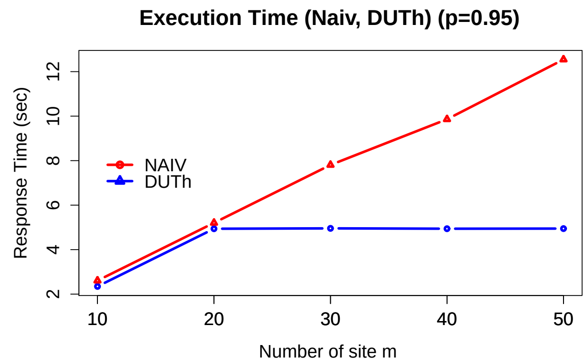

Fig. 7. Scalability of `DUTh` with Zipf distribution by varying m.

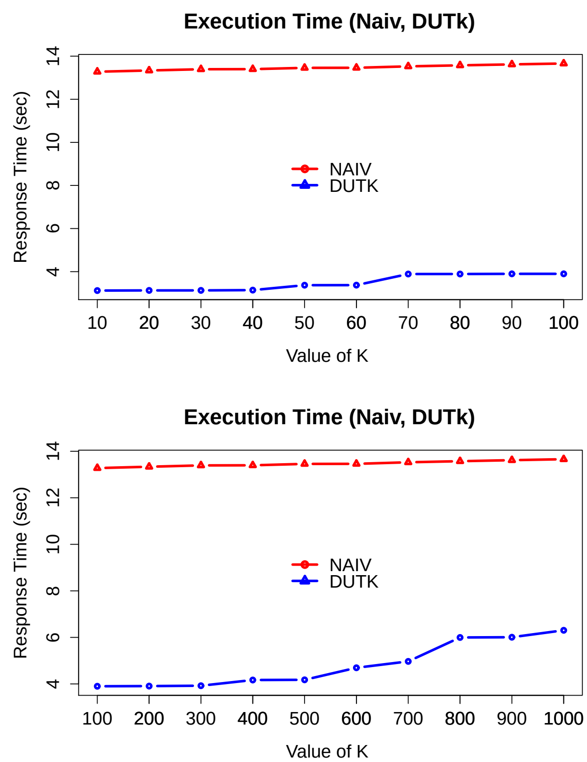

Fig. 8. Efficiency of `DUTk` with pairwise distribution by varying k.

B. Scalability of `DUTh`

In this experiment, we study the scalability of the `DUTh` algorithm with respect to the number of distributed nodes using Zipf distribution. To do so, we fixed the size of the whole distributed data and we varied the number of distributed sites from 10 to 50. Fig. 7 shows the results of the fixed threshold probability ($\tau = 0.95$).

We note that the gap between `DUTh` and `NAIV` when $m > 20$ increases as m increases due to the fact that only a subset of sites is requested based on GUI (only 20 sites have maximal probability of value d above 0.96). Consequently, the number of sites who have a maximal probability less than threshold τ, do not effect the query processing. This clearly shows the benefit of the GUI index in terms of scalability.

C. Efficiency of `DUTk`

In this subsection, we investigate the computation time of the `DUTk` algorithm. More precisely, we compare the computation time of `DUTk` and `NAIV` over different values of k. In Fig. 8(a) and 9(a), k is in the range $[10, 100]$, for the (b) figures, it is in the range $[100, 1000]$. As these figures clearly show, `DUTk` is substantially faster than `NAIV`. Furthermore, the computation time of `DUTk` is highly stable relative to the variations of k. This demonstrates the advantages of the GUI index in terms of time processing.

D. Effectiveness of `DUTk`

We compared the proposed `DUTk` algorithm with the `NAIV` method, over different k, i.e. $k \in [10, 100]$ and $k \in [100, 1000]$. Fig. 10 (a) and 11 (a) show the communication cost of the two algorithms for different values of k over the data sets generated, respectively with the Pairwise and Zipf distributions. Interpreting our findings is straightforward: from the experimental results, we can see that `DUTk` involves substantially fewer tuples than the `NAIV`. Moreover, we note that the number of returned tuples is greater than k which demonstrates the effectiveness of `DUTk`.

Furthermore, for different value of k, the communication cost of `DUTk` algorithm is smaller then `NAIV`. Consequently, using the GUI index yields a better communication cost and ensures returning the requested tuples. The second important point observed in this experiment is that the number of tuples transferred using `DUTk` is always greater than the value of k

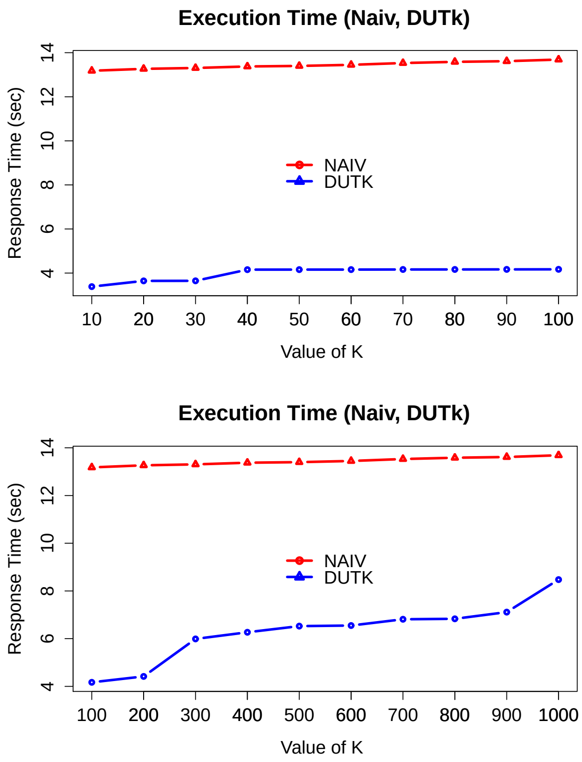

Fig. 9. Efficiency of `DUTk` with Zipf distribution by varying k.

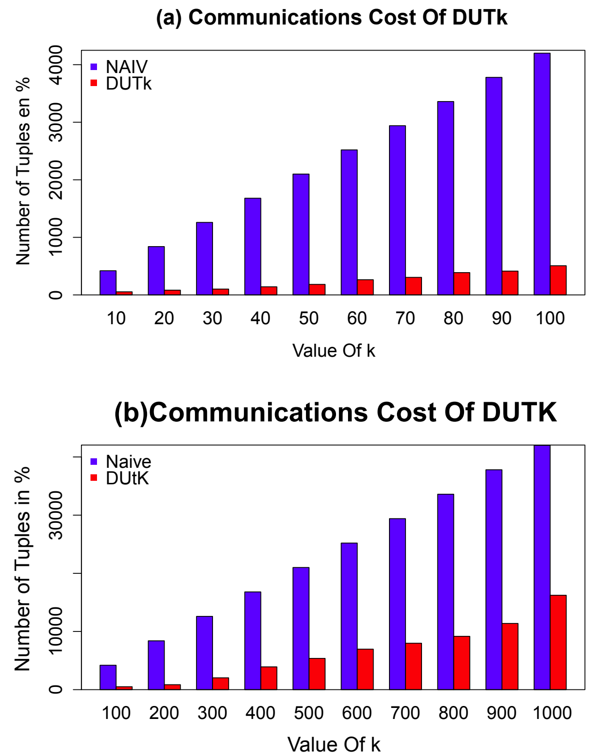

Fig. 11. `DUTk` with Zipf distribution by varying k.

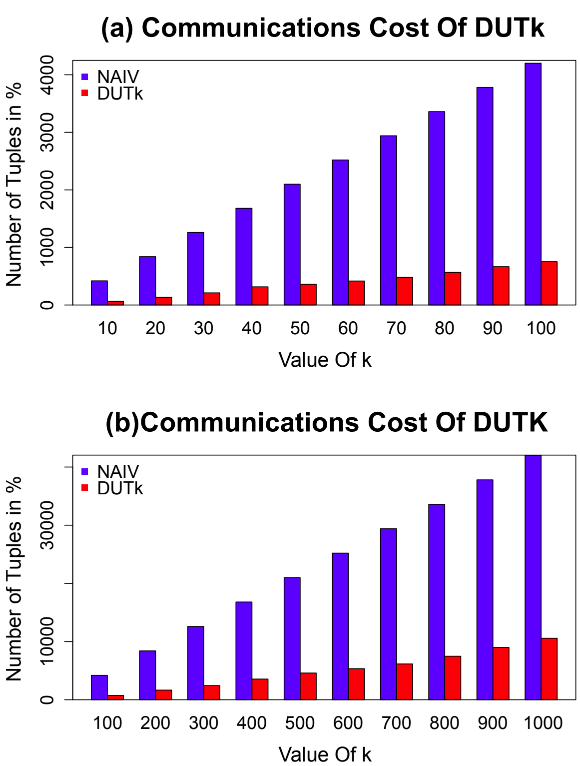

Fig. 10. `DUTk` with pairwise distribution by varying k.

which proves the effectiveness of our results.

E. Scalability of `DUTk`

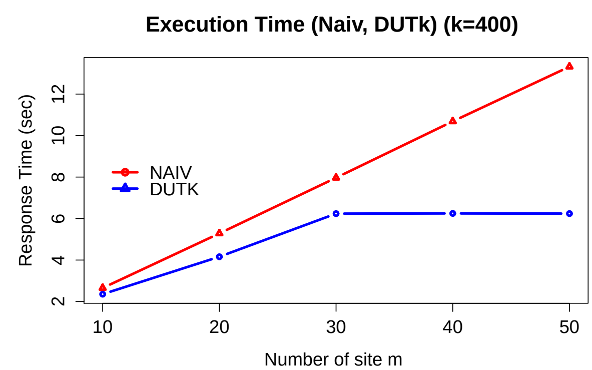

Fig. 12. Scalability of `DUTh` with Zipf distribution by varying m.

In this experiment, we study the scalability of our algorithm with respect to the number of distributed sites m. We keep the size of the whole distributed data unchanged and vary the number of sites from 10 to 50. We use the Zipf Data set in this experiment. Fig. 12 shows the results for $k = 400$. `DUTk` scales well with the number of sites m and outperforms `NAIV` substantially.

We note that the gap between `DUTk` and `NAIV` increases as m increases from $m > 30$. Fig. 12 clearly shows that the execution time of `DUTk` for $m > 30$ is constant.

This result is expected due to the fact that the only a subset of sites are queried based on the GUI. Consequently, the number of sites does not effect the query processing. This clearly shows the benefits of the index structures in terms of scalability.

VIII. Conclusion

In this paper, the problem of indexing and query processing over uncertain categorical data in distributed environments was addressed. An original approach was proposed to efficiently answers queries over distributed uncertain data using a distributed top-level index with *Local Uncertain Indexes (LUIs)* at local nodes and a *Global Uncertain Index (GUI)* summarizing local indexes. Leveraging the distributed indexing technique, we proposed a framework integrating two distributed algorithms `DUTh` and `DUTk` to process distributed uncertain threshold and top-k queries respectively.
An extensive experiment was conducted to illustrate the performance of the proposed framework, which performs distributed query processing and allows for minimal communication and processing costs as opposed to the naive(`NAIV`) approach.

We have seen that our proposed `DUTk` enhanced the naive approach that effectively and efficiently answers top-k queries over distributed uncertain data with minimum communication by using the proposed hierarchical index. However, during the ranking phase on the coordinator site, the tuples of some queried sites cannot be considered in the final result as shows in the effectiveness experiments. Hence, these sites should not be accessed and should be pruned to further reduce the communication cost and processing time.

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Accuracy Based Feature Ranking Metric for Multi-Label Text Classification

Muhammad Nabeel Asim
Al-Khwarizmi Institute of Computer Science,
University of Engineering and Technology,
Lahore, Pakistan

Abdur Rehman
Department of Computer Science,
University of Gujrat, Pakistan

Umar Shoaib
Department of Computer Science,
University of Gujrat, Pakistan

***Abstract*—In many application domains, such as machine learning, scene and video classification, data mining, medical diagnosis and machine vision, instances belong to more than one categories. Feature selection in single label text classification is used to reduce the dimensionality of datasets by filtering out irrelevant and redundant features. The process of dimensionality reduction in multi-label classification is a different scenario because here features may belong to more then one classes. Label and instance space is rapidly increasing by the grandiose of Internet, which is challenging for Multi-Label Classification (MLC). Feature selection is crucial for reduction of data in MLC. Method adaptation and data set transformation are two techniques used to select features in multi label text classification. In this paper, we present dataset transformation technique to reduce the dimensionality of multi-label text data. We used two model transformation approaches: Binary Relevance, and Label Power set for transformation of data from multi-label to single label. The Process of feature selection is done using filter approach which utilizes the data to decide the importance of features without applying learning algorithm. In this paper we used a simple measure (ACC2) for feature selection in multi-label text data. We used problem transformation approach to apply single label feature selection measures on multi-label text data; did the comparison of ACC2 with two other feature selection methods, information gain (IG) and Relief measure. Experimentation is done on three bench mark datasets and their empirical evaluation results are shown. ACC2 is found to perform better than IG and Relief in 80% cases of our experiments.**

Keywords*—Binary relevance (BR); label powerset (LP); ACC2; information gain (IG); Relief-F (RF)

I. Introduction

A feature is a measurable characteristic or property of the observed process. Text data is high dimensional in nature, and a moderate sized dataset may contain thousands of features. Multi-label is another important property of text data; i.e. a document can belong to none, one or more than one classes. In single label classification, documents belong to only one label (class) but in multi-label classification, which is a case in real world scenario like web pages, newspapers, sports magazine, data mining etc., a document can belong to more than one class that has become recent research topic [1] . Feature selection (FS) is a data pre-processing step in many machine learning applications, which plays an important role in reduction of dimensionality [24]. It helps in mitigating the computational requirements and understanding data. FS removes dimensionality by filtering out irrelevant features, thus improving the prediction capability of a classifier. Researchers evaluate the integrity of feature selection in two ways, individual and subset evaluation [12], [5]. Individual evaluation is computationally efficient it evaluate and assign the weights (ranks) to features (variables) according to their prediction ability in classification. It ignores the inter-dependency of features and also incapable of removing redundant features [21]. Subset evaluation handles redundancy and relevance of features, but it requires higher computational power. The main objective of feature selection is to select subset of features having stronger discrimination power [19]. It reduces effects of redundancy and noise variables by keeping only the features which are efficient for prediction [3].

If two features are extremely correlated as to showing dependence on each other, only one feature is sufficient for data description [17]. Dependent features give no extra information about data. The goal of feature selection is to obtain total information from fewer unique features containing maximum discrimination about the classes. In some applications, due to lack of information about the observed process, features having no correlation with the class act as noise. Such feature produce bias in classification process. Classifier efficiency is enhanced by feature selection techniques which give some cognizance about data and the process being observed.

From machine learning perspective to remove irrelevant features, feature selection criterion is required, which takes into account relevance of each feature with the output class. Irrelevant features lead to poor generalization of the predictor. Feature selection is not some dimensionality extraction technique like principle component analysis (PCA) [2], [20]. Since discriminative features may be independent of all the data, so a procedure called pruning is introduced after feature selection to find the subset of optimal features. To evaluate all the subset of features of size 2N, problem become NP-hard which is difficult to solve in polynomial time that's why a sub-optimal solution is incorporated which can eliminate redundant features with malleable computations. Subset feature selection deals with the scenario that some subset of features are selected while all others are ignored.

Recent research categorizes the multi-label classification into two broad domains: problem transformation and method adaptation. The former first converts multi-label data into single label data and then single label classification techniques are applied, while in latter case single label classifiers are extended to cope with multi-label data.

In multi-label text classification domain for the first time we introduce a well known feature selection technique ACC2, widely used in single label text classification for feature selection. In this paper e present a single label feature selection approach named ACC2 which is applied in conjunction with Binary Relevance and label power set. The presented technique is very fast and accurate compared to other two feature selection methods (IG, RF). To change the multi-label data into single label we use Binary Relevance (BR) and Label Powerset (LP) techniques.

BR transforms the original dataset into L datasets where L is the number of labels associated with the dataset. Each new dataset contains all the instances as in original dataset, but with only one class associated with each instance; and each of label value has only two states being either positive or negative. BR normally doesn't take into account the features correlation and fails to predict label ranking but it is light weight and reversible. Other advantage of BR is that independent features can be added or removed in model without disturbing rest of the model. In LP approach new classes are generated using possible combination of labels and then problem is solved using single label multi-class approach.

Remaining paper is distributed as: Related work is discuss in Section II. In Section II-B, we describe two label transformation methods and their basic theory. Basic concepts related to feature selection and its importance is discussed in Section III. Section VII introduces benchmark multi-label datasets and their statistics, while Section VI presents the most frequently used evaluation measures for multi-label learning. Results of feature selection algorithms on benchmark datasets are discuss in Section VIII.

II. Related Work

Feature selection is widely use to reduce the dimensionality of data. A number of comprehensive publications can be found on supervised, semi-supervised and non-supervised machine learning topics relating to features selection and classification domains [11], [12], [4], [18]. Multi-label feature selection approach using Relief and Information Gain (IG) is discussed in [13]. A novel approach which jointly performs feature selection with classification called the joint feature selection and classification for multi-label learning (JFSC) is proposed by [14]. Distribution based feature selection measure Chi square is used with label power set as a problem transformation technique [15]. Ensemble embedded feature selection (EEFS) a novel technique is propose by [16], , , , , they develop this method for the feature selection of multi-label clinical data.

To deal with multi-label classification variety of classifiers exist such as Ada-boost [26], BP-MLL [27], SVM [5], ML-KNN [25] each classifier has its own importance but ML-KNN is mostly preferred in most of the research work. In ML-KNN method Ecludean distance is measured between the unlabeled test example and the other instance of the training data set, then using the concept of maximum a posteriori (MAP) label for the test example is selected.

A. Multi-Label Learning

According to [5] multi-label learning has two categories: Multi-label Classification (MLC) and Label Ranking (LR). MLC is defined as a function $h_{MLC} : \chi \to 2^L$ where χ is an e-dimensional feature space and $L = \{\lambda_1, \lambda_2, \ldots, \lambda_r\}$ is an output space of $r > 1$ labels. Each subset of L is called label-set. If an input instance is given to classifier or predictor it will give a set of relevant labels, Y, and irrelevant labels, $\bar{Y}$. Hence, a bipartition of labels is obtained which is partitioning labels into relevant and irrelevant features. Generally speaking multi-class classification is a special case of MLC where $h_{MC} : \chi \to L$ while in binary classification $h_B : \chi \to \{0, 1\}$.

In Label ranking a function $f : \chi \times L \to R$ that returns ordering of all possible labels according to the relevance of labels in response to an input instance x. Thus a label λ_1 is ranked higher than other label λ_2 if it satisfies $f(x, \lambda_1) > f(x, \lambda_2)$. A rank function,$\tau_x$, maps the classifier real output values to the position of label in ranking, $\{1, 2, \ldots, r\}$. Hence, lower the position the better the label rank i.e. $f(x, \lambda_1) > f(x, \lambda_2) \Rightarrow \tau_x(\lambda_1) < \tau_x(\lambda_2)$. Fig. 1 [6] describes the basic taxonomy for feature selection in multi-label classification.

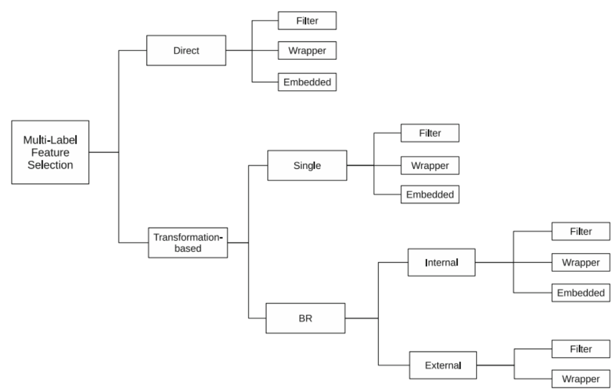

Fig. 1: Taxonomy for feature selection in multi-label classification.

B. Data Transformation Methods

Let X is an e-dimensional input space of numerical features. $L = \{\lambda_1, \lambda_2, \ldots, \lambda_r\}$ is an output space of $r > 1$ labels. A relation of features and labels is given as (x, Y) where $x = x_1, x_2, \ldots, x_e$, which is an e-dimensional instance associated to L set of labels as $Y_i \subseteq C$. Where $Y = \{y_1, y_2, \ldots, y_r\} = (0, 1)^r$ here Y is r-dimensional binary vector and label of each element is 1 if it is relevant, 0 otherwise. Table I shows the comparison of single label (binary, multi-class) data with multi-label one.

TABLE I: Single Label vs. Multi-label Dataset

Instances	Features	$Single - Label$ Binary	$Single - LabelMulti - Class$	$Multi - Label$				
		y ∈L ={0,1}	y ∈L ={λ_1,λ_2,λ_3,λ_4}	y_1	y_2	y_3	y_4	Y⊆L
1	f_1	0	λ_2	0	1	1	1	{λ_2,λ_3,λ_4}
2	f_2	1	λ_3	0	0	1	1	{λ_3,λ_4}
3	f_3	0	λ_4	1	1	0	0	{λ_1,λ_2}
4	f_4	1	λ_1	1	0	1	1	{λ_1,λ_3,λ_4}

Multi-label learning is categorized into two groups: method adaptation in which existing single label classifier models are enhanced to deal with multi-label data directly while second one is problem transformation methods which transform the multi-label problem into several binary classification problems (BR) or into different possible combinations of label set (LP).

C. Binary Relevance (BR)

It is like one-versus-all (OVA) approach, it generates one dataset for each label, in new generated dataset positive patterns represent the presence of a particular class label and all other patterns are set to negative. BR transforms the original dataset in to L datasets. Each new dataset contains all the instances as in original dataset, but with only one class; and each of feature value has only two states being either positive or negative. In the i_{th} dataset, if label set for an instance contains the i^{th} label then its label is positive otherwise negative. For classifying new pattern, it is assigned a class label by all the L datasets and the union of labels is the predicted label set. Although BR settles linearly with label set L of r dimensions; but it does not consider the correlation of labels.

Table III shows binary relevance (BR) based transformation of data from multi-label to single label when applied to the dataset of Table II.

TABLE II: Multi-label Dataset Example

Instances	Features	Label set
1	f_1	$\{\lambda_1,\lambda_3\}$
2	f_2	$\{\lambda_4\}$
3	f_3	$\{\lambda_1,\lambda_2,\lambda_3\}$
4	f_4	$\{\lambda_1,\lambda_2\}$

TABLE III: Dataset After BR Based Transformation

Instances	Label set
1	λ_1
2	- λ_1
3	λ_1
4	λ_1

Instances	Label set
1	- λ_2
2	- λ_2
3	λ_2
4	λ_2

Instances	Label set
1	λ_3
2	- λ_3
3	λ_3
4	- λ_3

Instances	Label set
1	- λ_4
2	λ_4
3	- λ_4
4	- λ_4

D. Label Power-set (LP)

In this approach each distinct combination of labels present in training set is treated as different class and then single-label classification is performed on the transformed data. Although this approach makes the task easy but with the increase in classes, label-set size also increases; hence increasing the computational cost and causes impediment in learning. The number of examples for training of each label set will be very small. To settle this problem, initial set of labels are split up into small random subsets of labels (label-sets). LP is performed on these label sets. This approach is called RAKEL, random k label sets, where k parameter specifies the size of label sets. Unlike BR, LP considers the correlation between labels. Table IV represents dataset formed after transformation using label power-set.

TABLE IV: Transformed Dataset using the Label Powerset Method

Instances	Labelset
1	$(\lambda_{1,3})$
2	(λ_4)
3	$(\lambda_{1,2,3})$
4	$(\lambda_{1,2})$

Let $C = \{\omega_i : i = 1, 2, \ldots, L\}$ be a finite set of classes, x_i is a, instance linked with set of labels Y_i where $Y_i \subseteq C$. A label set such that $S \subseteq C$ and $k = |S|$, is called $k - labelset$. Commonly used label sets are:

- Disjoint label-sets.
- Overlapping label-sets.

In disjoint label-set, each label set is of size k, and all label sets are disjoint; class label set C is randomly segregated into $l = [\frac{L}{k}]$ label sets, S. While in overlapping case label sets may overlap; C^k, overlapping label sets is the set of distinct $k - labelsets$ where $|C^k| = \binom{n}{k}$. To classify a new instance z, every classifier, h_i gives a binary prediction for each label in relative label-set, S_i. Nevertheless after the transformation it is possible to have limited number of combinations for new classes, hence producing sample imbalance issue.

III. Feature Selection

In this section basic concepts related to feature selection and its importance is discussed. In FS we cater the best features, which relatively provides more information of instance category to the classifier. In FS we find most suitable subset of features $X' \subseteq X$ that may enhance prediction capability of the classifier. There are basically three FS approaches: filter, wrapper and embedded. We discuss each one with detail.

A. Wrapper Approach

Wrapper methods find the most suitable subset of relevant features using the classification/learning algorithm; it offers high computation cost as it has to run classification task for each subset of features. As the number of features increases, the classification is required more often to find the suitable subset of features; thus giving arise to polynomial time tough scenario. To overcome the computational burden and to find most suitable subset of features, searching algorithm are incorporated.

There are different search algorithms for feature selection, each having its pros and cons. Tree structure is used in branch and bound approach [10] for selection of features; its complexity increases exponentially with increase in number of features. For large datasets with a huge number of features, exhaustive search approach is not appropriate. There are feasible linear approaches which yield good result with lesser computation cost i.e. sequential search, particle swarm optimization, genetic algorithm and heuristic search algorithms. Wrapper methods further split up into two categories: sequential search and heuristic search algorithms.

Sequential search algorithm continue to add/remove features until a maximum objective function is reached. A criterion is set whose objective is to maximize the objective function with minimal number of features. Sequential search algorithms are iterative in nature.

Sequential feature selection algorithm starts with an empty set; accumulate a single feature that yields maximal value for objective function. Wrapper approach necessitate the learning algorithm to find suitable set of features, but it is inclined towards finding the set of features which are more suitable for a particular learning algorithm; a rigorous computation power is required for the wrapper approach.

B. Embedded Approach

Embedded approach integrates feature selection with the training algorithm as some part of the process, like decision trees; selection of best features, having paramount discriminative power to differentiate among classes, at each stage.

C. Filter Methods

Filter methods selects sets of optimal features based on the peculiarity and idiosyncrasy of the dataset; irrelevant features are filtered out, this whole process is separate from the learning phase/algorithm. Variable ranking technique is the major method used in filters for feature selection in ordered form. Ranking methods are versatile thats why they hugely contribute to the practical applications. A particular ranking measure is used to rank the features with respect to some threshold; features below this threshold are discarded.

Basic trait of a relevant/distinctive feature is that it preserves the necessary information about classes present in the dataset. This trait is the relevance of feature necessary for segregation of distinct classes. But how could feature relevancy be described by current standards? Different researchers describe it differently. In [7] author defines an irrelevant feature as: "an irrelevant feature is conditionally independent of class labels". This fact depicts that a relevant feature can not be independent of class labels, but it can be independent of input data. This also suggests that relevant features have a certain amount of influence on the classes, if not then they should be considered as irrelevant. One most important parameter in determining the feature relevancy is feature correlation between features and classes; which describes a feature's importance to discriminate classes.

In this paper, we used ACC2 feature selection measure on multi-label text data and compared with two other well known filter based methods (Relief F and Information Gain). In Sections III-C1, III-C2 and III-D, we discuss these techniques in detail.

1) Relief F measure: It is heuristic approach developed by [8] removes the irrelevant features from the datasets. It is the extension of basic Relief algorithm [9]. Relief is capable of dealing with discrete as well as continuous attribute but it can't deal with multi-class problems. It estimates features on the basis of discrimination power value of attributes among the instances. Relief F seek for k nearest misses $M_j(C)$, $j = 1 \ldots k$, for each class C. Calculate the weight/estimate by taking average contribution of each class.

$$W[A] = W[A] - \sum_{j}^{k} \frac{diff(A, R, H_j)}{n \times k} + \sum_{C \neq class(R)} \sum_{j}^{k} \left[\frac{P(C)}{1 - P(class(R))} \times \frac{diff(A, R, M_j)}{n \times k} \right] \quad (1)$$

In above equation R is a randomly selected instance, for which Relief searches for its two nearest neighbors: one from the same class, called nearest hit H, and the other from the different class, called nearest miss M. It updates the quality estimation W [A] for all attributes A depending on their values for instance R, M and H . If instances R and H have different values of the attribute A then the attribute A separates two instances with the same class which is not desirable so we decrease the quality estimation W [A]. In (1) different function calculates the difference between two instances on the basis of nearest hit and nearest miss.

Basic idea about the working is that it separates classes pair on the basis of features regardless the fact that which two classes are nearest to each other.

2) Information Gain (IG): Information gain represents dependency of input labels with the class labels. It is defined by well-known equation of Shannon's about entropy:

$$H_{entropy}(Y) = \sum_{y} p(y) log(p(y)) \quad (2)$$

Actually entropy is the uncertainty in output label Y. Hence entropy in output, given input labels is:

$$H_{entropy}(y|x) = \sum_{x} \sum_{y} p(x, y) log(P(y|x)) \quad (3)$$

By already knowing the input labels we can predict output label Y with more accuracy. Hence IG relates the dependency of input label X to output label Y given as:

$$I(X, Y) = H_{entropy}(Y) - H_{entropy}(y|x) \quad (4)$$

D. ACC2 Feature Selection Measure

Accuracy measure (ACC) is a well known feature selection technique widely used in single label text classification. It is simply the difference of true positives and false positives of a term. It works well in balanced dataset but perform poorly on unbalanced dataset because this algorithm is biased toward tp.

Balanced Accuracy measure($ACC2$) is an enhanced version of accuracy measure (ACC)[22]. ACC2 is the absolute difference of true positive rate (tpr) and false positive rate (fpr). As tpr is normalized; obtained after division with the class size; it solves the problem of biasing toward tp. In multi label text classification we, for the first time, use this simple technique for feature selection. Formulae of ACC and ACC2 are given in (5) and (6,) respectively.

$$Accuracy\ Measure = ACC = |t_p - f_p| \quad (5)$$

$$Balanced\ Accuracy\ Measure = ACC = |t_{pr} - f_{pr}| \quad (6)$$

$$tpr = \frac{t_p}{t_p + f_n} \quad (7)$$

$$tpr = \frac{t_p}{t_p + f_n} \quad (8)$$

IV. Proposed Methodology

In multi-label text classification, we present a well known feature selection measure ACC2; which is widely used in single label text classification. We compare the performance of ACC2 with two (Information gain, Relief-F) other feature selection measures. We first use Binary Relevance (BR) and Label Power-Set for data transformation. To reduce the dimensionality of data we did feature selection.

Description of feature selection methods with transformation techniques is given below:

1) ACC2-BR: ACC2 as feature selection measure based on BR
2) ACC2-LP: ACC2 as feature selection measure based on LP
3) RF-LP: RF as feature selection measure based on LP
4) RF-BR: RF as feature selection measure based on BR
5) IG-BR: IG as feature selection measure based on BR
6) IG-LP: IG as feature selection measure based on LP

Relief-F is a univariate feature selection measure; it demarcates or evaluate the quality of features of single label datasets. Relief-F award different score for features having different values on different classes but castigates features having different values for the same class.

Information gain used the entropy measure between labels and features showing dependency between features and labels (classes). Features having greater values of IG are ranked higher. Entropy is the impurity present in the instances/examples, while information gain is an average reduction in entropy in accordance with a given feature. Higher the value of IG, better is the dependence between features and classes.

Balanced accuracy measure is most widely used algorithm in single label text classification. It takes the absolute difference of true positive rate (tpr) and false positive rate (fpr). Detailed expressions of three feature selection measures are given in Section III.

RF-BR, IG-BR and ACC2-BR first transform the multi-label dataset into single label datasets using binary relevance transformation, then feature selection methods RF, IG and ACC2 are applied to select the highly discriminative features among the classes. But in these methods, as the BR does not consider the correlation between labels during transformation, the same problem exist in these approaches.

In RF-LP, IG-LP and ACC2-LP methods the process of feature selection is done after transformation of data from multi-label to singe label using label power-set technique. Data transformation techniques are described in Section II-B.

After feature selection the process of classification is done using ML-KNN classifier. We use four well known evaluation measures (Hamming Loss, Subset accuracy, Micro and Macro average F measure) to estimate the accuracy of three feature selection algorithms.

V. Motivation Example

This section discusses the working of six feature ranking metrics with the help of an example. Table V is a sampled dataset presented only for illustration and comparison of different metrics based on problem transformation. We have 15 documents belonging to 3 classes and 10 terms/features. We practically show that multi-label data after transformation to single label becomes highly unbalanced. It is not a problem in single label feature selection regime. In multi-label classification due to multi label to single label transformation problems do exist; as binary relevance does not take into consideration the label dependency. On the other hand, LP only considers the distinct label-sets. It is, therefore, unable to predict new label-sets, causing over-fitting of training data. However, these techniques are light weight giving results almost comparable to problem adaptation techniques.

Table VI shows comparison of six ranking metrics and scored assigned by these metrics to features. In multi-label datasets, features can have relevance with more than one classes. So it is very difficult to judge the discrimination power of particular feature with respect to class labels. So many factors are to consider in multi-label domain for rank assignment. As can be seen that IG-BR and ACC2-BR assigned first rank to f_{10} while RF-LP and RF-BR assigned first rank to f_4. From V, one can estimate that f_{10}, f_9 and f_8 are more important as they highly match with three classes. But RF-LP and RF-BR assigned the first rank to f_4. Other metrics assigned lower ranks to this feature. In multi-label domain, features correlation between themselves and with all the class labels should also be considered.

TABLE V: Artificially Sampled Dataset for Multi-label

S no	f_1	f_2	f_3	f_4	f_5	f_6	f_7	f_8	f_9	f_{10}	C_1	C_2	C_3
1	1	0	1	1	0	0	1	0	1	1	1	1	1
2	1	1	1	1	0	0	1	0	0	1	1	1	0
3	0	0	1	1	1	0	1	0	0	0	0	0	0
4	1	0	1	0	0	1	1	0	0	1	1	1	0
5	1	0	1	0	0	1	0	1	1	1	0	0	1
6	1	0	0	1	1	0	0	0	0	0	0	0	0
7	1	1	1	0	0	0	0	1	0	0	1	1	1
8	1	0	0	0	1	1	0	1	1	0	1	1	1
9	0	0	0	1	0	0	0	1	1	1	0	0	0
10	1	1	0	0	0	1	0	1	1	0	1	1	1
11	0	1	0	0	0	1	0	1	1	1	1	1	1
12	0	1	1	0	0	0	1	1	1	1	1	1	1
13	1	1	1	0	0	1	0	1	1	1	1	1	1
14	1	1	1	0	1	0	0	1	1	1	1	1	1
15	1	1	0	0	0	1	1	1	1	0	0	1	1

TABLE VI: Comparison of Rank Assignee Metrics to Features on Sampled Dataset

term	f_1	f_2	f_3	f_4	f_5	f_6	f_7	f_8	f_9	f_{10}
RF-LP	-0.0375	-0.066	0.0797	-0.02	0.0043	-0.066	0.181	0.291	0.538	0.516
RF-BR	0.0271	0.2525	-0.0348	0.2909	0.0293	-0.0053	-0.0388	0.137	0.137	-0.0303
IG-BR	0	0.1256	0	0	0	0	0	0	0.1216	0.3758
IG-LP	0	0	0	0	0	0	0	0	0.734	0.61
ACC2-BR	0.0742	0.0818	0.2454	0.1424	0.206	0.1651	0.1681	0.2424	0.556	0.6727
ACC2-LP	0.1674	0.167	0.2929	0.1565	0.1459	0.1224	0.2525	0.3314	0.3995	0.3641
Rank RF-LP	9	4	7	1	10	6	5	3	2	8
Rank RF-BR	6	2	9	1	5	7	10	4	3	8
Rank IG-BR	10	9	3	4	5	6	7	8	2	1
Rank IG-LP	9	10	3	4	5	6	7	8	1	2
Rank IG-ML	7	1	9	2	6	5	8	3	4	10
Rank Acc-BR	10	9	3	8	5	7	6	4	2	1
Rank Acc2-LP	6	7	4	8	9	10	5	3	1	2

VI. Evaluation Measures

Evaluation measures used for multi-label classification are different from those used for single label classification. Evaluation Measures fall into two categories: label based and example based. Label based is an extended form of evaluation measures used for single label classification domain. Example based is specifically built for multi-label domain [28]. Here we give the expressions of evaluation measures used for multi-label classification. In all below evaluation measures x is label predicted KNN classifier and y is actual or true label.

$$\begin{aligned} Hamming\, loss(x_i, y_i) = H_{loss} &= \frac{1}{N}\sum_{i=1}^{N}\frac{|x_i \Delta y_i|}{L} \\ &= \frac{1}{N}\sum_{i=1}^{N}\frac{Xor(x_i, y_i)}{L} \end{aligned} \tag{9}$$

Hamming loss is an average measure of difference between actual and predicted value for labels. A low value of hamming loss is required to show better classification performance.

$$Accuracy = \frac{1}{N}\sum_{i=1}^{N}|\frac{x_i \cap y_i}{x_i \cup y_i}| \quad (10)$$

Accuracy is the closeness of the measure value to the known standard value. It is a fraction of correctly classified instances to the total number of instances to be classified. In multi-label classification accuracy of a metric is measure using above equation.

$$Precision = \frac{1}{N}\sum_{i=1}^{N}|\frac{x_i \cap y_i}{x_i}| \quad (11)$$

Precision is the fraction of correctly classify instances to the total number of instances to be classify.

$$Recall = \frac{1}{N}\sum_{i=1}^{N}|\frac{x_i \cap y_i}{y_i}| \quad (12)$$

Recall shows the fraction of number of correct instances to the total number of retrieved instances.

$$Subset\,accuracy = \frac{1}{N}\sum_{i=1}^{N}I(x_i = y_i) \quad (13)$$

Subset accuracy or classification accuracy is defined by (10). It is very strict requirement, as it is the average of set of predicted labels exactly matching the set of actual labels.

$$F_1 - Measure = \frac{1}{N}\sum_{i=1}^{N}2 \times \frac{|x_i \cap y_i|}{|x_i| + |y_i|}| \quad (14)$$

F_1 measure is a single measure obtained by combining two evaluation measures precision and recall. It is use to make trade off between precision and recall.

$$F_a(Macro\,averaged) = \frac{1}{q}\sum_{i=1}^{q}\frac{2t_p}{2t_p + f_p + f_n} \quad (15)$$

In macro F_1 measure we calculate the precision and recall of each set and take there average.

$$F_a(Micro\,averaged) = \frac{\sum_{i=1}^{q}2t_p}{\sum_{i=1}^{q}2t_p + \sum_{i=1}^{q}f_p + \sum_{i=1}^{q}f_n} \quad (16)$$

In micro F_1 measure we find the t_p, f_p and f_n of all the available sets and then apply them in (16) to calculate the final score. In equation q represents the available sets. A high value of accuracy and other evaluation criterion is required to show better classification performance, except for hamming loss metric.

VII. Experimental Setup and Datasets

We performed experiments on three benchmark text datasets given in Table VII. Preprocessing, such as stemming and stop word removal was already done on these data sets available at $(mulan\,dataset)$. We used Java platform for experimentation. Transformation of data from multi-label to single label is done using Binary Relevance (BR) and Label Powerset (LP) techniques. After data transformation feature selection algorithms are applied to reduce the dimensionality of data. The process of classification is done using ML-KNN classifier. The performance of feature selection algorithms is measure on percentage (10%, 20%, 30%, 40%, 50%,60%, 70%, 80%) of top ranked features selected by every algorithm. We used five (Hamming Loss, Ranking Loss, Subset accuracy, Micro and Macro average measure) evaluation measures to test the performance of six feature selection algorithms at different test points of data.

TABLE VII: Description of Datasets

Dataset	N	M	$\|L\|$	LC	LD	DC
bibtex	7395	1836 d	159	2.402	0.02	2856
Enron	1702	1001 d	53	3.38	0.06	753
medical	978	1449d	45	1.25	.03	94

Table VII shows benchmark datasets that are used in experimental evaluation for feature selection. Table also represents the characteristics of six datasets, such as number of instances (N); number of features (F); number of class labels (L); the label cardinality (LC); label density (LD); and distinct combinations of labels (DC).

$$Label\,Cardinality = \frac{1}{N}\sum_{i=1}^{N}\sum_{j=1}^{L}y_j^{(i)} \quad (17)$$

Label cardinality (LC) shows the average number of labels per example/instance. It can be calculated using above equation. In (17) N is number of instances and L represent number of labels in a sample.

$$Label\,Density = \frac{\frac{1}{N}\sum_{i=1}^{N}\sum_{j=1}^{L}y_j^{(i)}}{L} \quad (18)$$

Label density (LD) is normalized form of LC shown in (18).

For each dataset D, feature reduction measure for feature selection can be calculated from (19).

$$Feature\,Reduction(D, X') = 100 - \frac{100 \times X'}{M} \quad (19)$$

Where, X' is the feature subset obtained after feature selection from dataset D; M is the number of examples. Six feature selection techniques are performed on each dataset. classifier response is evaluated for features that are selected.

VIII. RESULTS

We applied six FS methods and five evaluation measures on three benchmark datasets. Tables VIII, XII and XVI shows the hamming loss measure for described datasets. Hamming loss is the relative frequency of predicted and actual labels as previously shown in (9). Subset accuracy (10) is another measure, which tell that either a predicted label is the actual true label or not. Micro averaged precision results are shown in Tables X, XIV and XVIII. In micro averaged precision large classes dominate over small classes, as it is the fraction of true positives and $tp + tn$ of all concerned classes. F1 measure is the harmonic mean of precision and recall, it considers the true positives and ignores the true negatives but this measure assigns equal weight to precision and recall. Whereas precision is the number of actual correct results out of the marked correct results by the classifier $\frac{t_p}{t_p+f_p}$; and 'recall' is the fraction of correct results out of all the correct results $\frac{t_p}{t_p+f_n}$[23]. Macro average measure is more biased towards average recall than average precision. Label based micro average criterion is biased towards most populated labels, while macro average is the average of tp and fp for each class separately. Macro averaging is biased to least populated classes.

A. Enron Dataset

Enron dataset is a test bench dataset available at $(mulan\, dataset)$, having 1702 instances and 53 labels with cardinality 3.78. Tables VIII to XI show the experiments done on Enron dataset and in next subsections we discuss their results based on different measures.

1) Hamming Loss: Table VIII shows the hamming loss for six feature ranking measures based on filter approach on Enron dataset. Hamming loss is computed for different data test points for selected features. Least-BR shows those BR problem transformation based feature ranking measures having least hamming loss; Least-LP shows those feature ranking measures having least hamming loss among other measures for LP transformation case. As can be seen from Table VIII, ACC2 produces the least hamming loss both in BR as well as LP transformation case. It is the simplest technique among all described approaches.

TABLE VIII: Feature Ranking Metrics Having Least Hamming Loss using KNN Classifier

Hamming Loss								
Features	10%	20%	30%	40%	50%	60%	70%	80%
IG-BR	0.063	0.0646	0.066	0.068	0.0663	0.0645	0.0614	0.0635
RF-BR	0.0617	0.0598	0.0614	0.0635	0.0616	0.0613	0.0618	0.0614
ACC2-BR	0.0613	0.0605	0.0613	0.0633	0.0613	0.0637	0.063	0.0612
Least-BR	ACC2-BR	RF-BR	ACC2-BR	ACC2-BR	ACC2-BR	RF-BR	IG-BR	ACC2-BR
IG-LP	0.0613	0.059	0.0629	0.0624	0.0616	0.0619	0.0617	0.0618
RF-LP	0.0622	0.0604	0.0622	0.0623	0.0617	0.0618	0.0623	0.0623
ACC2-LP	0.0599	0.0625	0.0619	0.0618	0.0621	0.0625	0.063	0.0617
Least-LP	ACC2-LP	IG-LP	ACC2-LP	ACC2-LP	IG-LP	RF-LP	IG-LP	ACC2-LP

2) Subset Accuracy: Subset accuracy values of six feature ranking metrics are given in Table IX. Max-BR shows the occurrence of a measure, among three other measure based on BR problem transformation approach, having maximum subset accuracy value. In same way Max-LP shows a measure having the maximum subset accuracy value among other techniques based on LP transformation approach. Clearly, ACC2 measure subset accuracy is leading to all other techniques.

TABLE IX: Subset Accuracy Values for Feature Ranking Metrics using KNN Classifier on Enron Dataset

Subset Accuracy								
Features	10%	20%	30%	40%	50%	60%	70%	80%
IG-BR	0.0039	0.0235	0.0215	0.0196	0.0274	0.0274	0.0313	0.0352
RF-BR	0.0333	0.0215	0.0254	0.0215	0.0274	0.0215	0.0372	0.0411
ACC2-BR	0.045	0.0274	0.0274	0.0196	0.0313	0.0275	0.0294	0.0333
Max-BR	ACC2-BR	ACC2-BR	ACC2-BR	RF-BR	ACC2-BR	ACC2-BR	RF-BR	RF-BR
IG-LP	0.0391	0.0333	0.0254	0.0235	0.0313	0.0313	0.0254	0.0301
RF-LP	0.0333	0.0235	0.0196	0.0254	0.0274	0.0235	0.0254	0.0294
ACC2-LP	0.0294	0.0196	0.0294	0.0255	0.0294	0.0235	0.0372	0.0303
Max-LP	IG-LP	IG-LP	ACC2-LP	ACC2-LP	IG-LP	IG-LP	ACC2-LP	ACC2-LP

3) Micro and macro averaged F1-score: In Table X, we compare different feature ranking criterion based on BR and LP transformation approaches at different number of selected features. RF-BR performed better than IG-BR and ACC2-BR in micro-averaged case in BR domain. In LP domain, ACC2-LP is leading while IG-BR performed poorer. RF-BR approach outperformed in macro-averaged case while ACC2-LP outperformed in LP case. Whereas IG-BR as well as IG-LP underperformed in both micro and macro cases.

4) Ranking loss: Table XI shows ranking loss for different feature selection criteria. ACC2-BR has the least ranking loss for 30, 50, 60 and 80 percent of selected features. For 20, 40 and 70 percent of test points RF-BR has the least ranking loss; IG-BR has only least ranking loss at 10 percent of selected data points. For LP case, RF-LP and ACC2-LP has three times least ranking loss, while IG-LP has two times least ranking loss. Hence, overall ACC2 method outperformed for LP and BR cases.

B. Medical Dataset

Results for experiments of different measures on Medical dataset are presented in Tables XII to XV. Subsequent section present discussion of these measures.

1) Hamming loss for medical dataset: hamming loss for different metrics of medical dataset is given in Table XII. ACC2 has the least hamming loss for 9 out of 16 cases at different number of selected features. RF has least hamming loss for 4 cases, and IG has least hamming loss in 3 out of 16 cases.

2) Subset accuracy measure for medical dataset: For medical dataset, ACC2-BR has the maximum subset accuracy for 10% to 30% of total number of features (see Table XIII). While for 40% to 80% of total number of features, RF-BR has the maximum accuracy. In LP case, ACC2-LP gives the maximum subset accuracy only for 40% and 70% of features. IG underperformed in medical datasets, while RF technique take the maximum value in 10 out of 16 cases.

3) Micro and macro-average F1-score for medical dataset: In Table XIV combined values for micro and macro-averaged F1- score are given for medical dataset. Out of 16 calculations at different percentages ACC2 take the maximum micro-averaged value for 8 times while IG performed better than RF both in BR and LP case by taking 5 times max values of micro-averaged score. ACC2-BR becomes highest at 20% to 50% of selected features. ACC2-LP becomes highest at 30%, 50%, 70% and 80% of selected features. While IG-BR and IG-LP performed better than RF-BR and RF-LP in macro-average measure in medical dataset.

TABLE X: Micro and Macro-averaged F1-Score Values for Feature Ranking Metrics using KNN Classifier on Enron Dataset

Micro-averaged F-Measure								
Features	10%	20%	30%	40%	50%	60%	70%	80%
IG-BR	0.3066	0.3525	0.3722	0.3474	0.3781	0.4141	0.4405	0.4593
RF-BR	0.436	0.4813	0.4618	0.466	0.4868	0.4835	0.4879	0.4848
ACC2-BR	0.450	0.4413	0.4724	0.4534	0.4722	0.4659	0.4759	0.4871
Max-BR	ACC2-BR	RF-BR	ACC2-BR	RF-BR	RF-BR	RF-BR	RF-BR	ACC2-BR
IG-LP	0.4401	0.4738	0.4755	0.4841	0.4947	0.4853	0.4762	0.487
RF-LP	0.433	0.4721	0.4814	0.4967	0.5053	0.4845	0.492	0.4793
ACC2-LP	0.4504	0.4598	0.4857	0.4994	0.49	0.487	0.4788	0.4982
Max-LP	ACC2-LP	IG-LP	ACC2-LP	ACC2-LP	RF-LP	ACC2-LP	RF-LP	ACC2-LP
Macro-averaged F-Measure								
Features	10	20	30	40	50	60	70	80
IG-BR	0.0859	0.0928	0.0985	0.0915	0.102	0.1194	0.1217	0.1383
RF-BR	0.1212	0.135	0.134	0.133	0.1402	0.1414	0.1432	0.1494
ACC2-BR	0.1047	0.1106	0.1295	0.1363	0.1321	0.1376	0.1458	0.1464
Max-BR	RF-BR	RF-BR	RF-BR	ACC2-BR	RF-BR	RF-BR	ACC2-BR	RF-BR
IG-LP	0.109	0.1238	0.1272	0.1352	0.1434	0.1408	0.1369	0.137
RF-LP	0.1092	0.1243	0.133	0.1409	0.1469	0.1429	0.1371	0.1363
ACC2-LP	0.1145	0.1263	0.1406	0.1434	0.1399	0.1437	0.1409	0.1567
Max-LP	ACC2-LP	ACC2-LP	ACC2-LP	ACC2-LP	ACC2-LP	ACC2-LP	ACC2-LP	ACC2-LP

TABLE XI: Ranking Loss Values for Feature Ranking Metrics using KNN Classifier on Enron Dataset

Ranking Loss								
Features	10%	20%	30%	40%	50%	60%	70%	80%
IG-BR	0.0445	0.0533	0.0628	0.062	0.0618	0.0654	0.0654	0.0654
RF-BR	0.0429	0.0499	0.0592	0.0576	0.0567	0.0577	0.0567	0.0567
ACC2-BR	0.0584	0.0511	0.0581	0.063	0.0564	0.0574	0.0574	0.0564
Least-BR	IG-BR	RF-BR	ACC2-BR	RF-BR	ACC2-BR	ACC2-BR	RF-BR	ACC2-BR
IG-LP	0.0483	0.0536	0.0578	0.0627	0.0608	0.0674	0.0574	0.0574
RF-LP	0.0476	0.0555	0.061	0.0589	0.0604	0.0624	0.0545	0.0545
ACC2-LP	0.0768	0.0677	0.0651	0.0691	0.0601	0.0618	0.0518	0.0618
Least-LP	RF-LP	IG-LP	IG-LP	RF-LP	ACC2-LP	ACC2-LP	ACC2-LP	RF-LP

TABLE XII: Hamming Loss Values for Feature Ranking Metrics using KNN Classifier on Medical Dataset

Hamming Loss								
Features	10%	20%	30%	40%	50%	60%	70%	80%
IG-BR	0.0097	0.0098	0.0101	0.0101	0.0099	0.0095	0.0095	0.0095
RF-BR	0.0108	0.0103	0.0098	0.0102	0.0102	0.0102	0.0102	0.0102
ACC2-BR	0.0103	0.0096	0.001	0.01	0.0098	0.0094	0.0094	0.009
Least-BR	IG-BR	ACC2-BR	ACC2-BR	ACC2-BR	ACC2-BR	ACC2-BR	ACC2-BR	ACC2-BR
IG-LP	0.0098	0.0098	0.0097	0.01	0.0099	0.0096	0.0096	0.0096
RF-LP	0.0097	0.0099	0.0099	0.0096	0.0093	0.0094	0.0092	0.0092
ACC2-LP	0.0018	0.0106	0.0107	0.0103	0.01	0.01	0.01	0.0091
Least-LP	ACC2-LP	IG-LP	IG-LP	RF-LP	RF-LP	RF-LP	RF-LP	ACC2-LP

4) Ranking loss: ACC2-BR attains least value of ranking loss when we select top 50% to 80% of features in Table XV. RF-BR attains least value at approximately mid point of selected features. For LP case RF and ACC2 attains least values by going side by side while IG performance deteriorates both as compared to RF and ACC2 metrics.

TABLE XIII: Subset Accuracy Values for Feature Ranking Metrics using KNN Classifier on Medical Dataset

Subset Accuracy								
Features	10%	20%	30%	40%	50%	60%	70%	80%
IG-BR	0.6426	0.6689	0.6587	0.6621	0.6621	0.6689	0.6689	0.6689
RF-BR	0.6382	0.6553	0.6558	0.6655	0.6621	0.6655	0.6655	0.6655
ACC2-BR	0.6621	0.6724	0.6621	0.6587	0.6587	0.6587	0.6587	0.6587
Max-BR	ACC2-BR	ACC2-BR	ACC2-BR	RF-BR	RF-BR	RF-BR	RF-BR	RF-BR
IG-LP	0.6758	0.6758	0.6724	0.6587	0.6621	0.6621	0.6621	0.6621
RF-LP	0.6826	0.6826	0.6826	0.666	0.6962	0.6894	0.6797	0.6997
ACC2-LP	0.6041	0.6519	0.6519	0.6719	0.6519	0.6519	0.6819	0.6519
MAX-LP	RF-LP	RF-LP	RF-LP	ACC2-LP	RF-LP	RF-LP	ACC2-LP	RF-LP

C. Bibtex Dataset

Table XVI to XIX discusses results for different metrics on bibtex dataset. Bibtex is a benchmark dataset having 7395 documents and 1836 features having a total size of 7395×1836 with cardinality of 2.402.

1) Hamming loss measure of bibtex dataset: Least value of ACC2 occurred for BR transformation for initially 10% to 30% and then 70% to 80% features among IG-BR and RF-BR techniques. While for 40% to 60% of features, IG-BR attained

TABLE XIV: Micro and Macro-averaged Values for Feature Ranking Metrics using KNN Classifier on Medical Dataset

Micro-averaged F-Measure								
Features	10%	20%	30%	40%	50%	60%	70%	80%
IG-BR	0.8042	0.8254	0.819	0.8207	0.8218	0.8228	0.8318	0.8318
RF-BR	0.8006	0.8137	0.804	0.8179	0.8163	0.8179	0.8179	0.8179
ACC2-BR	0.8127	0.8267	0.8216	0.8186	0.8254	0.8254	0.8254	0.8254
MAX-BR	ACC2-BR	ACC2-BR	ACC2-BR	IG-BR	ACC2-BR	ACC2-BR	IG-BR	IG-BR
IG-LP	0.823	0.8254	0.8266	0.8202	0.8218	0.8206	0.8286	0.8286
RF-LP	0.827	0.8229	0.8243	0.8221	0.8342	0.8211	0.8358	0.8358
ACC2-LP	0.7776	0.8266	0.8082	0.8232	0.8211	0.8251	0.8211	0.8211
MAX-LP	IG-LP	ACC2-LP	IG-LP	ACC2-LP	RF-LP	ACC2-LP	RF-LP	RF-LP
Macro-averaged F-Measure								
Features	10	20	30	40	50	60	70	80
IG-BR	0.5618	0.5649	0.5745	0.5748	0.5761	0.5778	0.5778	0.5778
RF-BR	0.5139	0.5657	0.568	0.5714	0.5709	0.5714	0.5714	0.5714
ACC2-BR	0.5109	0.5679	0.5756	0.5757	0.5764	0.5764	0.5764	0.5764
MAX-BR	IG-BR	ACC2-BR	ACC2-BR	ACC2-BR	ACC2-BR	IG-BR	IG-BR	IG-BR
IG-LP	0.5419	0.5732	0.5769	0.5759	0.5761	0.577	0.577	0.577
RF-LP	0.5639	0.5719	0.5755	0.5765	0.5761	0.5776	0.5707	0.5707
ACC2-LP	0.4261	0.5176	0.5791	0.5662	0.5778	0.5738	0.5738	0.5738
MAX-LP	RF-LP	IG-LP	ACC2-LP	RF-LP	ACC2-LP	RF-LP	ACC2-LP	ACC2-LP

TABLE XV: Ranking Loss Values for Feature Ranking Metrics using KNN Classifier on Medical Dataset

Ranking Loss								
Features	10%	20%	30%	40%	50%	60%	70%	80%
IG-BR	0.0445	0.0533	0.0628	0.062	0.0618	0.0654	0.0654	0.0654
RF-BR	0.0429	0.0599	0.0592	0.0576	0.0567	0.0587	0.0567	0.0567
ACC2-BR	0.0584	0.0511	0.0581	0.063	0.0564	0.0574	0.0564	0.0564
Least-BR	RF-BR	ACC2-BR	ACC2-BR	RF-BR	ACC2-BR	ACC2-BR	ACC2-BR	ACC2-BR
IG-LP	0.0483	0.0536	0.0618	0.0627	0.0608	0.0574	0.0574	0.0574
RF-LP	0.0476	0.0555	0.061	0.0589	0.0607	0.0624	0.0545	0.0545
ACC2-LP	0.0768	0.0677	0.0601	0.0691	0.0605	0.0618	0.0508	0.0618
Least-LP	RF-LP	IG-LP	ACC2-LP	RF-LP	ACC2-LP	IG-LP	ACC2-LP	RF-LP

the least hamming loss value. On the other hand RF-BR did not take least value of hamming loss measure in BR domain. For LP case ACC2 and RF-BR generated the least hamming loss values, as shown in Table XVI.

TABLE XVI: Hamming Loss Values for Feature Ranking Metrics using KNN Classifier on Bibtex Dataset

Hamming Loss								
Features	10%	20%	30%	40%	50%	60%	70%	80%
IG-BR	0.0132	0.0137	0.0141	0.014	0.0143	0.0143	0.0147	0.0145
RF-BR	0.0141	0.0141	0.0145	0.0142	0.0146	0.0146	0.0146	0.0145
ACC2-BR	0.0124	0.0135	0.014	0.0146	0.0147	0.0148	0.0145	0.0142
Least-BR	ACC2-BR	ACC2-BR	ACC2-BR	IG-BR	IG-BR	IG-BR	ACC2-BR	ACC2-BR
IG-LP	0.0147	0.0149	0.0144	0.0148	0.0149	0.0148	0.0147	0.0146
RF-LP	0.0145	0.0148	0.0145	0.0147	0.0148	0.0148	0.0148	0.0148
ACC2-LP	0.0144	0.0154	0.0149	0.0153	0.0154	0.0147	0.015	0.0145
Least-LP	ACC2-LP	RF-LP	IG-LP	RF-LP	RF-LP	ACC2-LP	IG-LP	ACC2-LP

2) Subset accuracy measure for bibtex dataset: The comparison of IG, RF, ACC2 is shown in Table XVII for BR and LP transformation case on different percentages of total number of features. ACC2-BR took the lead in BR case attaining maximum values in five cases among other two techniques, while in LP case, RF took the same lead among other two techniques.

3) Micro and macro averaged F1-score for bibtex dataset: ACC2-BR acquired highest values of micro-averaged score for 50% to 80% of top selected features while top 10% and 20% of selected features, IG-BR attained higher values. RF-BR only attained max value on 30% of features. In LP case ACC2 and IG-LP attained maximum values in two cases of micro-averaged measure, while RF attained higher values than other measures in 4 cases (Table XVIII). In this case, for both LP and BR transformations RF and ACC2 attained maximum values in 5 out of 16 cases. IG attained maximum values in 6 out of 16 cases, in both transformation cases.

4) Ranking Loss for bibtex dataset: Table XIX shows the ranking loss of six different metrics; and the metrices attained the least ranking score among the six metrices. In bibtex case, IG for BR and LP transformation cases attained least values for ranking loss measures in 7 cases, while RF remained highest in 5 out of 16 cases. ACC2 attained least ranking loss in 4 out of 16 cases.

TABLE XVII: Subset Accuracy Values for Feature Ranking Metrics using KNN Classifier on Bibtex Dataset

Subset Accuracy								
Features	10%	20%	30%	40%	50%	60%	70%	80%
IG-BR	0.1407	0.1542	0.1429	0.1402	0.1362	0.1333	0.1348	0.1321
RF-BR	0.101	0.1317	0.1298	0.1348	0.133	0.1327	0.133	0.138
ACC2-BR	0.0947	0.1082	0.1303	0.1407	0.1384	0.1347	0.1394	0.1387
Max-BR	IG-BR	IG-BR	IG-BR	ACC2-BR	ACC2-BR	ACC2-BR	ACC2-BR	ACC2-BR
IG-LP	0.0974	0.1136	0.1425	0.128	0.1389	0.1447	0.1317	0.1276
RF-LP	0.1001	0.1303	0.1434	0.1416	0.1407	0.1375	0.1353	0.1303
ACC2-LP	0.0947	0.1315	0.124	0.1204	0.1136	0.1244	0.1367	0.128
MAX-LP	RF-LP	ACC2-LP	RF-LP	RF-LP	RF-LP	IG-LP	ACC2-LP	RF-LP

TABLE XVIII: Micro and Macro-averaged F1-Score Values for Feature Ranking Metrics using KNN Classifier on Bibtex Dataset

Micro-averaged F-Measure								
Features	10%	20%	30%	40%	50%	60%	70%	80%
IG-BR	0.1879	0.2541	0.258	0.2765	0.262	0.2802	0.2707	0.2766
RF-BR	0.1544	0.2186	0.2617	0.2634	0.2634	0.2714	0.2682	0.2639
ACC2-BR	0.1311	0.209	0.2474	0.259	0.2692	0.2804	0.2728	0.2785
Max-BR	IG-BR	IG-BR	RF-BR	IG-BR	ACC2-BR	ACC2-BR	ACC2-BR	ACC2-BR
IG-LP	0.1213	0.1933	0.2336	0.2433	0.2599	0.2737	0.2752	0.277
RF-LP	0.1157	0.2063	0.246	0.2643	0.2742	0.2755	0.2725	0.2751
ACC2-LP	0.0913	0.1448	0.2002	0.2192	0.2368	0.2474	0.2768	0.2775
MAX-LP	IG-LP	IG-LP	RF-LP	RF-LP	RF-LP	RF-LP	ACC2-LP	ACC2-LP
Macro-averaged F-Measure								
Features	10%	20%	30%	40%	50%	60%	70%	80%
IG-BR	0.163	0.222	0.225	0.244	0.241	0.248	0.239	0.237
RF-BR	0.131	0.195	0.205	0.232	0.234	0.243	0.238	0.235
ACC2-BR	0.113	0.183	0.226	0.231	0.243	0.251	0.243	0.24
Max-BR	IG-BR	IG-BR	ACC2-BR	IG-BR	ACC2-BR	ACC2-BR	ACC2-BR	ACC2-BR
IG-LP	0.105	0.17	0.204	0.218	0.237	0.245	0.249	0.247
RF-LP	0.099	0.182	0.218	0.238	0.249	0.248	0.242	0.245
ACC2-LP	0.077	0.126	0.174	0.19	0.208	0.219	0.226	0.239
MAX-LP	IG-LP	RF-LP	RF-LP	RF-LP	RF-LP	RF-LP	IG-LP	IG-LP

TABLE XIX: Ranking Loss Values for Feature Ranking Metrics using KNN Classifier on Bibtex Dataset

Ranking Loss								
Features	10%	20%	30%	40%	50%	60%	70%	80%
IG-BR	0.213	0.1929	0.1825	0.1841	0.174	0.1761	0.1707	0.1747
RF-BR	0.248	0.2141	0.204	0.1863	0.1815	0.1807	0.1784	0.1761
ACC2-BR	0.2606	0.2201	0.202	0.1837	0.1813	0.1732	0.1701	0.1724
Least-BR	IG-BR	IG-BR	IG-BR	ACC2-BR	IG-BR	ACC2-BR	ACC2-BR	ACC2-BR
IG-LP	0.2744	0.2229	0.1979	0.1922	0.1749	0.1754	0.1662	0.1641
RF-LP	0.2727	0.2247	0.1997	0.1799	0.1696	0.1706	0.1627	0.1692
ACC2-LP	0.2791	0.2466	0.2149	0.2032	0.1816	0.1826	0.1712	0.1714
Least-LP	RF-LP	IG-LP	IG-LP	RF-LP	RF-LP	RF-LP	RF-LP	IG-LP

IX. Discussion

We present a feature selection technique in multi-label text classification. We demonstrated the comparative study of six feature selection metrices, three for BR and three for LP case, for multi-label text classification. ACC2 measure is very simple technique and requires less computations as compared to other metrices. Despite its simplicity, It's performance is comparable to other complicated metrices as shown in Tables XX to XXII. It can be seen from Table XX, least hamming and ranking loss for Enron dataset is attained by ACC2 measure. These are %age of number of selected features assigned to each case out of eight cases for each of BR and LP case. Hence in all three datasets, ACC2-BR has 70.8% least hamming loss among the six metrices; ACC2-LP attains least hamming loss in 33.33% cases. Overall, least ranking loss for three datasets for ACC2-BR is 58.33% and 25% for ACC2-LP case. While the subset accuracy, micro, macro-averaged measures are computed for maximum values among the six feature ranking metrices.

TABLE XX: Percentage of a Feature Ranking Metric Producing Highest Subset Accuracy, Micro, Macro Average F1 Measure and Producing Lowest Hamming and Ranking Loss Enron Dataset

EValuation	FR Metrics using BR Transformation			FR Metrics using LP transformation		
MEasures	IG	Rf	ACC2	IG	RF	ACC2
Hamming Loss	12.5	25	62.5	37.5	12.5	50
Subset Accuracy	0	37.5	62.5	50	0	50
Micro-averaged F-Measure	0	62.5	37.5	12.5	25	62.5
Macro-averaged F-Measure	0	75	25	0	0	100
Ranking Loss	12.5	37.5	50	25	37.5	37.5

TABLE XXI: Percentage of a Feature Ranking Metric Producing Highest Subset Accuracy, Micro, Macro Average F1 Measure and Producing Lowest Hamming and Ranking Loss Bibtex Dataset

Evaluation	FR Metric using BR			FR Metric using LP transformation		
Measure	IG-BR	Rf-BR	ACC2-BR	IG-LP	RF-LP	ACC2-LP
Hamming Loss	37.5	0	62.5	37.5	37.5	25
Subset Accuracy	37.5	0	62.5	12.5	62.5	25
Micro F	37.5	12.5	50	25	50	25
Macro f	37.5	0	62.5	37.5	62.5	0
Ranking Loss	50	0	50	37.5	62.5	0

TABLE XXII: Percentage of a Feature Ranking Metric Producing Highest Subset Accuracy, Micro, Macro Average F1 Measure and Producing Lowest Hamming and Ranking Loss Medical Dataset

Evaluation	FR Metric using BR Transformation			FR Metric using LP Transformation		
Measure	IG-BR	Rf-BR	ACC2-BR	IG-LP	RF-LP	ACC2-LP
Hamming Loss	12.5	0	87.5	25	50	25
Subset Accuracy	0	62.5	37.5	0	75	25
Micro-averaged F-Measure	37.5	0	62.5	2	37.5	37.5
Macro f	50	0	50	12.5	37.5	50
Ranking Loss	0	25	75	25	37.5	37.5

X. Conclusion

In this paper, we evaluate the performance of three feature ranking algorithms and two data transformation techniques by using five evaluation measures on three benchmark datasets. For data transformation techniques from multi-label to single label, we conclude that binary relevance doesn't take into consideration the label dependency. While on other hand LP only consider the distinct labelsets, hence unable to predict new labelsets causing over-fitting of training data.

In feature ranking algorithms Relief F measure does not deal with redundant features. Rather then converting a multi-nomial classification problem into binomial classification problem, RELIEFF searches for k near misses from each different class and averages their contributions for updating W, weighted with the prior probability of each class. Information gain capture the amount of information present in a feature for the purpose of automatic text classification. ACC2 select highly discriminative features which occur more time in one class but less times in other class. In future work, we will adopt ACC2 measure to directly deal with multi-label data.

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AUTHORS' PROFILES

Muhammad Nabeel Asim received his Bachelor degree from University of Management and Technology (UMT) and Masters degree in Electrical Engineering from University of Engineering and Technology, Lahore, Pakistan. Currently working as Research Officer at Al-Khawarizmi Institute of Computer Science (KICS) University of Engineering and Technology (UET), Lahore, Pakistan. His research interests are Bioinformatics, Artificial Intelligence, Information Retrieval,Natural Language Processing and Text classification.

Dr. Abdur Rehman completed his PhD from UET Lahore in computer science. During his PhD, he has been part of Al-Khawarizmi Institute of Computer Science, UET Lahore for 8 year working as a researcher on different posts. His core expertise are in the field of machine learning and his focused area of research is "Text Classification". He is currently working as Assistant Professor in Department of Computer Science, University of Gujrat, Pakistan.

Dr. Umar Shoaib did his PhD in Department of Computer and Control Engineering Politecnico di Torino, Italy. His current research interests include Machine Learning, Robotics, Text Mining, Scalable Networks, Interfaces, Cloud Computing, Natural Language Processing, Text mining and Internet of Things.

Design of a Microstrip Patch Antenna with High Bandwidth and High Gain for UWB and Different Wireless Applications

Zain Ul Abedin and Zahid Ullah
Department of Electrical Engineering, CECOS University of IT & Emerging Sciences, Peshawar, Pakistan

***Abstract*—We propose square shape patch antenna in this research work. Focus of the work is to obtain large bandwidth with compact ground plane for wireless applications. The proposed antenna is designed using dielectric material of FR4 having height of 1.6 mm and having ϵ_r of 4.4. We simulated the proposed antenna in CST Microwave Studio. Simulation results show that the proposed antenna achieved bandwidth from 2.33 GHz to 12.4 GHz with radiation efficiency more than 90% in ultra-wideband range. The proposed antenna covers the range of ultra wideband from 3.1 GHz to 10.6 GHz, the range of local area network, wide area network, and also covers the range of satellite communications (for both uplink and downlink).**

Keywords*—High bandwidth, patch antenna, low profile, linear polarization

I. Introduction

Antenna is one of the basic building blocks of wireless applications. Antenna plays an important role in telecommunication industry and is used to transmit and collect electromagnetic (EM) waves. Antenna is a metallic device acts as transducers, which transfers and also receives EM waves. Antennas are present everywhere; at homes, automobiles, roads, houses, police stations, radar system, parks, satellite communications buildings, and military devices. Television antennas in early days are manufactured to receive the air broadcast signals; those signals are transmitted having frequency at about 41 MHz to 250 MHz in very high frequency and also 470 MHz to 960 MHz in ultra-high frequency ranges among different countries.

In the end of 20^{th} century, scientists were able to do many inventions like computers, mobile phones, laptops, local area network, bluetooth, routers, jammers, military missile applications, aircraft, satellites communication, and rockets. For the reason of those inventions, scientists need such an antenna which is light in weight, cheap in cost, having good performance, portable, and easy to fabricate. Microstrip patch antenna can be printed on circuit boards. Microstrip patch antennas are mostly used in mobiles phones and laptops, etc. Patch antennas are cheap in cost, having low profile, and easy to fabricate. Patch antennas have three parts−patch, substrate, and ground. Substrate is composed of dielectric materials such as Arlon, FR4, foam, polystyrene, and roger. Ground and patch are made from metals.

The patch antennas are a famous type of the antennas from the frequency range of 1 GHz to 11 GHz. Deschamps suggested the idea of microstrip patch antennas in 1953. On the other hand, in early 1970, Howell and Munson were able to design a practical antenna. The antennas they designed have dual dimensional arrangements and are normally identified as patch antennas. The common arrangement of patch antenna can be made up of a radiator on front side of the substrate while a ground plane on the back side of patch antenna. There are various shapes of patch antennas for example square, rectangular, circular, triangular, dipole, and elliptical. A lot of advantages of those antennas such as lesser volume, easy to integrate, and also have the ability to handle both linear and circular polarization, and to permit double and triple frequency operations. Feed lines and matching circuits can be fabricated jointly with the antennas design.

Patch antennas have some limitations as well such as its bandwidth is very small and gain is also not good. Thus, different techniques are developed to increase its bandwidths and gain. In this letter, the proposed antenna is square in shape, which operates in the range of 2.33 GHz to 12.4 GHz; thus, accomplishing the UWB bandwidth improvement. UWB range is from 3.1 GHz to 10.6 GHz, which is officially certified by federal communication commission at America in 2002.

The proposed antenna covers the ultra wideband range, also achieves the range of worldwide interoperability for microwave access (WIMAX-1(2.300-2.400GHz), WIMAX-2(2.496 to 2.690), WIMAX-3(3.300 to 3.800), and WIMAX-4 (5.25-5.85 GHZ)), local area network band (wifi-1(2.412 to 2.4835), wifi-2(4.9 to 5.9)) works in personal area network (Bluetooth(2.402 to 2.480)), also works in satellite communications bands for both downlink (3.7 to 4.2 GHz) and uplink (5.925 to 6.425 GHz).

Rest of the paper is organized as follows: Section II discusses problem statement, literature review, and outlines contributions of the work, Section III explains basic structure of the proposed antenna design, while Section IV shows its simulation results from CST Microwave Studio.

II. Background and Contributions

A. Problem Statement

The main limitation of microstrip patch antenna is the lower bandwidth, which effects wireless communication applications. Bandwidth of microstrip antenna can be improved by increasing the height of substrate by using the transmission line model. At the same time, increasing height of the substrate also increases the surface waves, which move from end to end around the substrate and spread at the curves of the radiating patch, which adopts apart of energy of the signal;

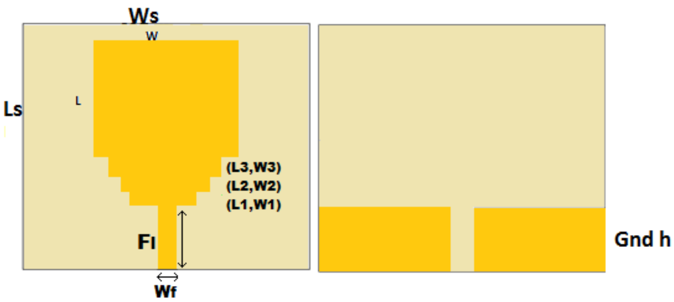

Fig. 1. Design of the proposed antenna.

thus, declining the the antenna's performance. In order to avoid this problem, different techniques are used such as air gap technique in which surface waves are not produced. Further, length of patch plays important role in bandwidth of antenna. Antennas having minimum possible size are considered efficient.

B. Related Work

Different antennas have been studied in the literature for illustration such as antenna having ring slot of square shape [1], antenna of dual band [2], planar antenna with single, dual, and triple-band notched characteristic [3], CPW-fed with SRR loaded UWB antenna [4], MIMO antenna for UWB applications [5], SRR loaded UWB circular monopole antenna [6], new planar antenna for UWB applications [7],and a printed circular monopole disc antenna [8].

In the literature, several methods are suggested to rise the bandwidth of antenna such as meandered ground plane method [9], patch antenna with integrated band pass filter [10], matching network of optimally designed, and gap-coupled feed [11]. All those methods are proposed to enhance the bandwidth of patch antenna. The proposed methods have advantage as well dis-advantages. Some methods are costly, some methods have very low gain and efficiency.

For the proposed antenna, all the advantages are collected and summarized to design a new antenna for wireless communications.

C. Contributions

- The proposed antenna bandwidth is improved, which is suitable for ultra wideband devices. The proposed antenna works in additional band and also achieved multiband characteristics.
- The proposed antenna is easy to fabricate, voltage standing wave ratio is also less than two, and gain is in the acceptable range.
- The proposed antenna has smaller size, lower profile in weight, and linearly polarized.

III. STRUCTURE OF THE PROPOSED PATCH ANTENNA

The basic antenna design is shown in Fig 1. For the proposed antenna, FR4 dielectric material is used for substrate having value of 4.4 and height of 1.6 mm. Our proposed antenna consists of two rectangular shapes patches−one large rectangular patch and another small rectangular patch, which also works as a feed line for the antenna. The substrate length and its width are denoted by *Ls* and *Ws*, respectively. The feed line is represented by *Fl*. Patch antenna is present on front side of the substrate while ground is also on the same side of the substrate. The ground plane is indicated by Gnd h as presented in Fig.1. CST Microwave Studio is used for antenna simulation in order to obtain more accurate results. All the dimensions of the antenna design are presented in Table I.

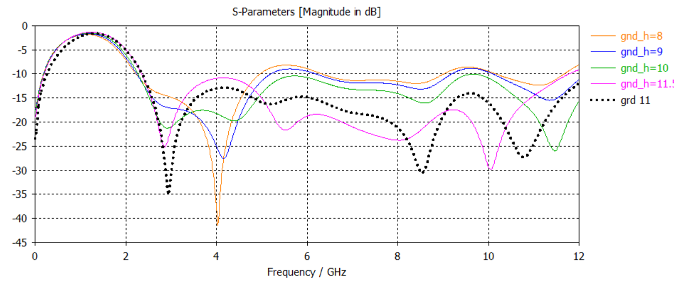

Fig. 2. Simulated return loss in dB against frequency for different length of ground plane.

TABLE I. DIMENSIONS OF THE PROPOSED ANTENNA

Parameter	Value(mm)	Parameter	Value(mm)
Sub. height	1.6	L1	3.2
Ls	40 (FR4)	L2	2.4
Ws	43	L3	1.2
Gnd h	11	W1	1. 6
Wf	3	W2	3.6
Fl	11.9	W3	6
Er	4.4	Ls	43 (other materials)

IV. SIMULATION RESULTS OF THE PROPOSED PATCH ANTENNA

A. Return Loss, S11

Simulated return loss of an antenna with different ground planes is shown in Fig.2. The proposed antenna is tested and its results are checked with five different ground planes widths starting from ground width equal to 8 to 11.5. From Fig.2 it is clear that ground plane having width of eleven gives better results than all other. Antenna with ground plane of eleven gives resonant frequencies at 2.94 GHz, 5.18 GHz, 8.54 GHz and 10.78 GHz through return loss of -35.056 dB, -16.335 dB, -30.589 dB and -27.27 dB. Patch of length L, ladder steps at bottom of patch and also ground plane creates those frequencies.

The frequencies for the reason that of the footsteps at the lowermost part of rectangular patch, the rapid changes in the geometry of patch antennas indications to a cutout in the microstrip line [12]. Due to the technique wider bandwidth is obtained, which produces capacitive coupling between the ground plane and patch of the antenna [13]. Magnetic and electric field spreading are altered nearby the discontinuity when the geometry of antenna ups and downs. Thus, the incoherence due to footsteps can be symbolized as corresponding circuit as three times of spilt LC circuit as shown in Fig. 3. Quasi static computation equations from (1) to (7) can be used to express the variables [12].

$$A = 0.00137\frac{\sqrt{\epsilon_{re1}}}{Zom1}(1-\frac{W2}{W1})h\frac{(\epsilon_{re1}+0.3)}{(\epsilon_{re1}-0.258)} \quad (1)$$

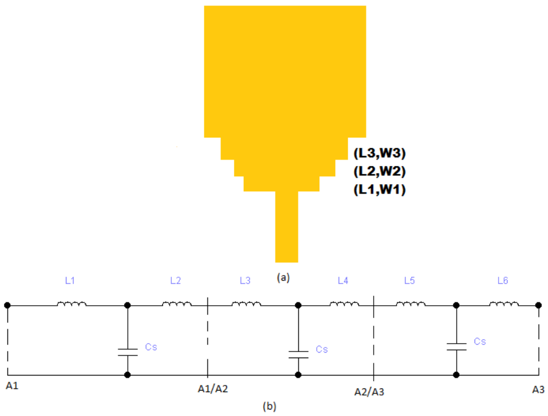

Fig. 3. (a) Micro-strip 3 steps pattern; (b) Corresponding circuit.

$$B = \frac{(\frac{W1}{h} + 0.264)}{(\frac{W1}{h} + 0.8)} \quad (2)$$

$$Cs = A \times B \quad (3)$$

$$L1 = \frac{Lw1}{(Lw1 + Lw2)} Ls \quad (4)$$

$$L2 = \frac{Lw2}{(Lw1 + Lw2)} Ls \quad (5)$$

$$Lwi = \frac{(Zom\sqrt{\epsilon_{re}})}{C}(H/m) \quad (6)$$

$$Ls = 0.000987h(1 - \frac{Zom1}{Zom2}\sqrt{\frac{(\epsilon_{re1}}{\epsilon_{re2})}})^2(nH) \quad (7)$$

Where, *Lwi* is on behalf of i = 1, 2, 3 point towards inductance per unit length of microstrip of widths *W1*, *W2* and *W3*. ϵ and *Zom* point towards the dielectric constant and microstrip patch line characteristic impedance and also the substrate size h is in mm [12].

Acting on radiating and matching areas permits monitoring the impedance bandwidth. This slot presents a capacitive reactance, which counteracts with the inductive reactance of the feed. In fact, the technique of cutting the slot at the patch antenna is investigated widely [12]. The proposed antenna shows decent ultra wideband features in terms of return loss and impedance BW, with fractional bandwidth(FBW) of 136.59% in the simulated result. Furthermore, from return loss graph, we can see the proposed antenna gives better result when ground length is 11 mm.

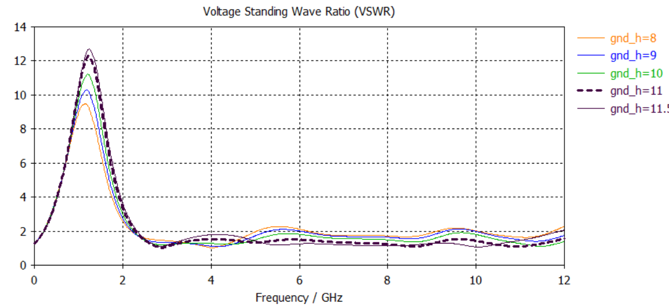

Fig. 4. Simulated VSWR against frequency.

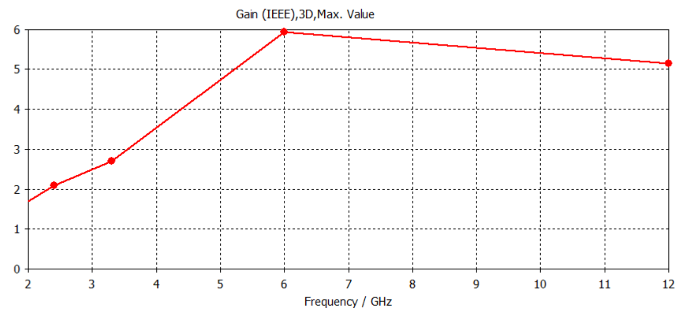

Fig. 5. Simulated result of Gain vs frequency (GHz).

B. Plot of Voltage Standing Wave Ratio (VSWR)

For different ground widths, the VSWR graph is checked against its frequencies. It is obviously understood that this graphs values are between one and three all the way through simulation frequency. For our attained results, the voltage standing wave ratio for ground width of 11 is good in which value is less than 2 all the way through the simulated frequency results as displayed in the Fig. 4.

C. Comparison of the Proposed Antenna

Table II gives a comparison of different antennas w.r.to their sizes, area and bandwidths achieved. The proposed antenna is simulated for different substrate materials and its results are checked and compared with different antennas as shown in Table II. All the antennas attained wideband properties. Now a day‘s, size of the antenna needs to be minimum due to invention of modern devices and bandwidth should be larger. The proposed antenna is not only smaller in size and area but also has larger bandwidth than all other antennas given in Table II. Gain (dBi) of an antenna is the ratio of power transferred by an antenna in a specified direction and the power transferred in that direction by a perfectly effective isotropic radiator in that direction. Fig. 5 shows the information about the gain along with frequency on horizontal side. It is noticed that the gain of antenna is positive and acceptable. Negative gain shows the losses of an antenna. Gain of the proposed antenna lies between 2 and 6 throughout the simulated frequency.

D. Radiation Pattern of an Antenna

E plane is the one at which the theta cuts of at 90^0 and H plane is that one at which phi cuts at 90^0. From Fig. 6, it can be seen that radiation patterns show a guiding performance

TABLE II. COMPARISON OF THE PROPOSED ANTENNA WITH DIFFERENT ANTENNAS

Ref.	Antenna type	Freq. (GHz)	ABW (GHz)	FBW	Material	Area (L×W)
[1]	Ring slot antenna	3-11	ABW = 8GHz	FBW = 114.2%	RO4003B ϵ_r = 3.4	12000m^2
[7]	Planar UWB antenna	3.1-10.6	ABW = 7.5GHz	FBW = 109.4%	RO4003 ϵ_r = 3.38	5850m^2
	Proposed antenna (using material RO4003)	2.35-13.5	ABW = 11.15GHz	FBW = 140.6%	RO4003 ϵ_r = 3.38	1849m^2
[3]	Planar antenna	2.5-12	ABW = 9.5GHz	FBW = 131.1%	RO3003h ϵ_r = 3	2500m^2
	Proposed antenna (using material RO3003)	2.38-13.82	ABW = 11.44GHz	FBW = 141.5%	RO3003 ϵ_r = 3.00	1849m^2
[4]	SRR-loaded UWB antenna	2.37-10.93	ABW = 8.56GHz	FBW = 128.7%	Taconic ϵ_r = 2.33	2500m^2
[6]	Circular monopole antenna	2.6-10.8	ABW = 8.2GHz	FBW = 122.3%	Taconic ϵ_r = 2.33	2500m^2
	Proposed antenna (using material Taconic)	2.4-14.55	ABW = 12.15GHz	FBW = 143.3%	Taconic ϵ_r = 2.33	1849m^2
[2]	Dual band antenna	2.8-10.6	ABW = 7.8GHz	FBW = 116.4%	FR4 ϵ_r = 4.6	1720m^2
[5]	MIMO antenna for UWB	3.1-12	ABW = 8.9GHz	FBW = 117.8%	FR4 ϵ_r = 4.4	1820m^2
[8]	Printed circular disc monopole	2.69-10.16	ABW = 7.47GHz	FBW = 116.2%	FR4 ϵ_r = 4.7	2100m^2
	Proposed antenna (using material FR4)	2.33-12.4	ABW = 10.064GHz	FBW = 136.5%	FR4 ϵ_r = 4.4	1720m^2

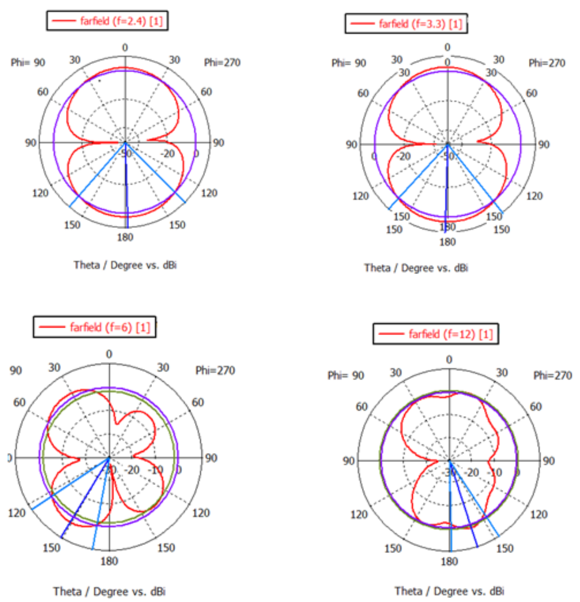

Fig. 6. Radiation patterns at phi cut of 0 degree and at theta cut of 90 degree at (a) 2.4 GHz, (b) 3.3 GHz, (c) 6 GHz, and (d) 12 GHz.

such as the core lobe direction is towards at 0^0 and 180^0. It means that absorption of the field concentrate on sides of patch of antenna. For time being, from the front and back part of the patch of an antenna lobe suppressed at 90^0 and 270^0 degree, respectively. Fig. 6(b) shows the same pattern as given in Fig. 6(a), while Fig. 6(c) and Fig. 6(d) display the central lobe direction at the front patch antenna from 0^0 to 180^0. More lobes are also observed at higher frequencies. The radiation pattern shows omni directional behavior at low frequencies and linear directional behavior at higher frequencies.

V. CONCLUSIONS AND FUTURE WORK

The proposed antenna showed good ultra wideband features, which have simulation results from 2.33 GHz to 12.4 GHz and fractional bandwidth of 136.59%. The proposed antenna also covers range of WIMAX, blue-tooth, wireless fidelity, and satellite communications for both uplink and downlink channels. The scale of VSWR is also less than 2 throughout the achieved bandwidth. The proposed antenna has small geometrical size and thus, is suitable for telecommunication applications. In future work, we will try to further increase the bandwidth and to add more communication bands for wireless applications such as global system for mobile communication and universal mobile telecommunications system.

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RGBD Human Action Recognition using Multi-Features Combination and K-Nearest Neighbors Classification

Rawya Al-Akam
Active Vision Group
Institute for Computational Visualistics
University of Koblenz-Landau
Universitatsstr. 1, 56070 Koblenz, Germany

Dietrich Paulus
Active Vision Group
Institute for Computational Visualistics
University of Koblenz-Landau
Universitatsstr. 1, 56070 Koblenz, Germany

***Abstract*—In this paper, we present a novel system to analyze human body motions for action recognition task from two sets of features using RGBD videos. The Bag-of-Features approach is used for recognizing human action by extracting local spatial-temporal features and shape invariant features from all video frames. These feature vectors are computed in four steps: Firstly, detecting all interest keypoints from RGB video frames using Speed-Up Robust Features and filters motion points using Motion History Image and Optical Flow, then aligned these motion points to the depth frame sequences. Secondly, using a Histogram of orientation gradient descriptor for computing the features vector around these points from both RGB and depth channels, then combined these feature values in one RGBD feature vector. Thirdly, computing Hu-Moment shape features from RGBD frames; fourthly, combining the HOG features with Hu-moments features in one feature vector for each video action. Finally, the k-means clustering and the multi-class K-Nearest Neighbor is used for the classification task. This system is invariant to scale, rotation, translation, and illumination. All tested, are utilized on a dataset that is available to the public and used often in the community. By using this new feature combination method improves performance on actions with low movement and reach recognition rates superior to other publications of the dataset.**

Keywords*—RGBD videos; feature extraction; K-means clustering; KNN (K-Nearest Neighbor)

I. INTRODUCTION

Human action recognition using cameras is a very active research topic and it has been widely studied in the computer vision and pattern recognition fields to characterize the behavior of persons. Also, it has been used in many applications fields like, video surveillance, robotics human-computer interaction, and a variety of systems that involve interactions between persons and computers [1]. Therefore, the ability to design a machine that is capable of interacting intelligently with a human-inhabited environment is important in recognizing humans and activities of people from the video frames [2].

In the last few years, research on human activity recognition essentially concentrated on recognizing human activities from videos captured by conventional visible light cameras [3]. But recently, the action recognition studies have entered a new phase by technological advances and the emergence of the low-cost depth sensor like Microsoft Kinect [4]. This depth sensor has many advantages over RGB cameras, like to provide 3D structural information as well as color image sequences in real time, and can even work in total darkness which makes it possible to explore the fundamental solution for traditional problems in human action classification [5], [6]. Of course, the depth camera also has severe limitations which can be partially enhanced by fusion of RGB and Depth. But all these advantages make it interesting to incorporate the RGBD cameras into more challenging environments.

Overview of our Approach: In this work, we combined two sets of features. For the local motion and appearance features, which are improved the method of [7], [8] to categorize the body motions on RGBD videos instead of using only RGB video, according to how to represent the spatial and temporal structure of actions from color and depth data together and combining the motion features extracted from both channels in one feature vector for each video action. And the Hu-moments shape invariant which introduced by [9] are used for global spatial-temporal features. The overview of the proposed approach is illustrated in Fig. 1. In order to represent the human activity recognition from RGBD, the two different sets of features vector are extracted, the first set is represented as follow:

- Detect the important interest points by extracting visually distinctive points from the spatial domain using Speed-Up Robust Features (SURF). After that filter these SURF points using Motion History Image (MHI) [10], [11] and Optical Flows (OF) [12] to extract only the essential motion points from the sequences.
- HOG descriptor is applied to describe the detected interest points. The HOG features is computed from the frames, MHI and OF channels and represented in one feature vector for each video action.

While the second feature set is computed as:

- Represent the spatial and temporal information about an action in a single image. In order to do this, MHI is used, where the pixel intensity is a function of the recency of action.
- Hu moments [9] are used as descriptors of the motion history image. We are using the seven translation,

scale and orientation invariant Hu moments to get seven Hu moments each from the motion history image.

After the two feature sets are computed, the feature vectors are combined and encoded into a single code by using the bag of features algorithm [13]. The unsupervised learning K-means clustering and supervised learning K-nearest neighbor (KNN) are used for classification the different action from videos.

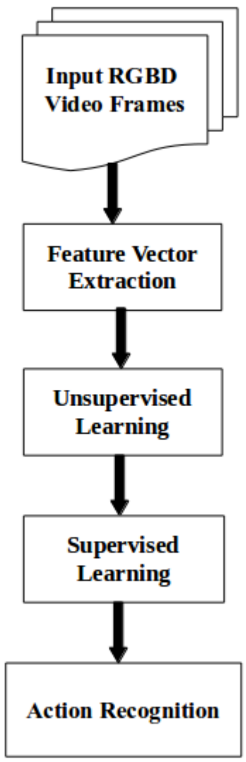

Fig. 1. General structure of our approach.

The rest of the paper is represented as follows: Section II describes the related work done in this area. Section III explain in detail the system analysis of action recognition. Section IV represent the experimentation and results, and finally Section V provides the conclusion.

II. RELATED WORKS

In this section, the state of the arts on human action recognition are summarized. During the last decades, several different approaches have been proposed to detection, representation and recognition, and understanding video events. Previous research on action recognition mainly focused on RGB videos, which yielded lots of feature extraction, action representation, and modeling methods.

In [14], the authors presented the human detection and simultaneous behavior recognition from RGB image sequences by using the action representation method depended on applying the clustering algorithm to the sequence of HOG descriptor of human motion images. Other people used a hierarchical filtered motion (HFM) method for recognizing the human action in crowded videos as in [7], they used 2D Harris corners for detection the motion interest points from motion history image (MHI) of the recent motion (i.e. locations with high intensities in MHI). Then applied a global spatial motion smoothing filter to the gradients of MHI to eliminate isolated unreliable or noisy motions. To characterize the spatial (appearance) and temporal (motion) features they used HOG descriptor in the intensity image and MHI, respectively and the Gaussian Mixture Model (GMM) classifier for action recognition performance system. The work of [15] also used the invariant 7-Hu moments of MEI and MHI to estimate Gaussian Mixtures models of daily activities.

In the other hand, there are a lot of researchers presented action recognition depending on only depth data, like in [16], they recognized human action by projected to the depth maps onto three orthogonal levels and collect the global activities from entire video frames to compute the Depth Motion Maps (DMM), after that the Histograms of Oriented Gradients (HOG) is computed from DMM to represent an action video.

A lot of researchers improved the action recognition performance on RGBD data by computing a local spatial-temporal feature from RGB data, a skeleton joint feature, and a point cloud feature in-depth data, and combined all these features based on sparse coding features combination methods as in [17]. While in [2], presented a comparison of several well-known pattern recognition techniques. they used Motion History Images (MHI) to describe these activities in a qualitative way and computed Hu-moments. And the system was tested extracted features vectors with Support Vector Machines and K-Nearest Neighbours classifiers. Another method that was used for action recognition is based on features learned from 3D video data applying Independent Subspace Analysis (ISA) technique on data collected by RGBD cameras as in [18] and they followed the bag-of-visual-word model and an SVM classifier to recognize the activities. The other researchers considered a human's activity as composed of a set of sub-activities as in [19], they computed a set of features based on human poses and motion, as well as based on image and point-cloud information.

III. SYSTEM ANALYSIS OF ACTION RECOGNITION

In this section, we describe the steps for computing the feature vectors from each video action in details. Section III-A represents the pre-processing to the input RGB and depth videos. Section III-B gives a brief description about Bag of Features Extraction. Section III-C explains the Bag of Words Generation and in Section III-D explains the classification method used to compute the recognition accuracy. As shown in Fig. 2, the system scheme of action recognition is represented.

A. Pre-processing Input Data

The input dataset is color and depth videos were analyzed as a frame sequence to extract features presented in each frame. In this work, we choose to use a lower resolution of 320×240 in order to reduce the computational complexity of the system. The depth maps data captured by the Kinect camera are often noisy due to imperfections related to the

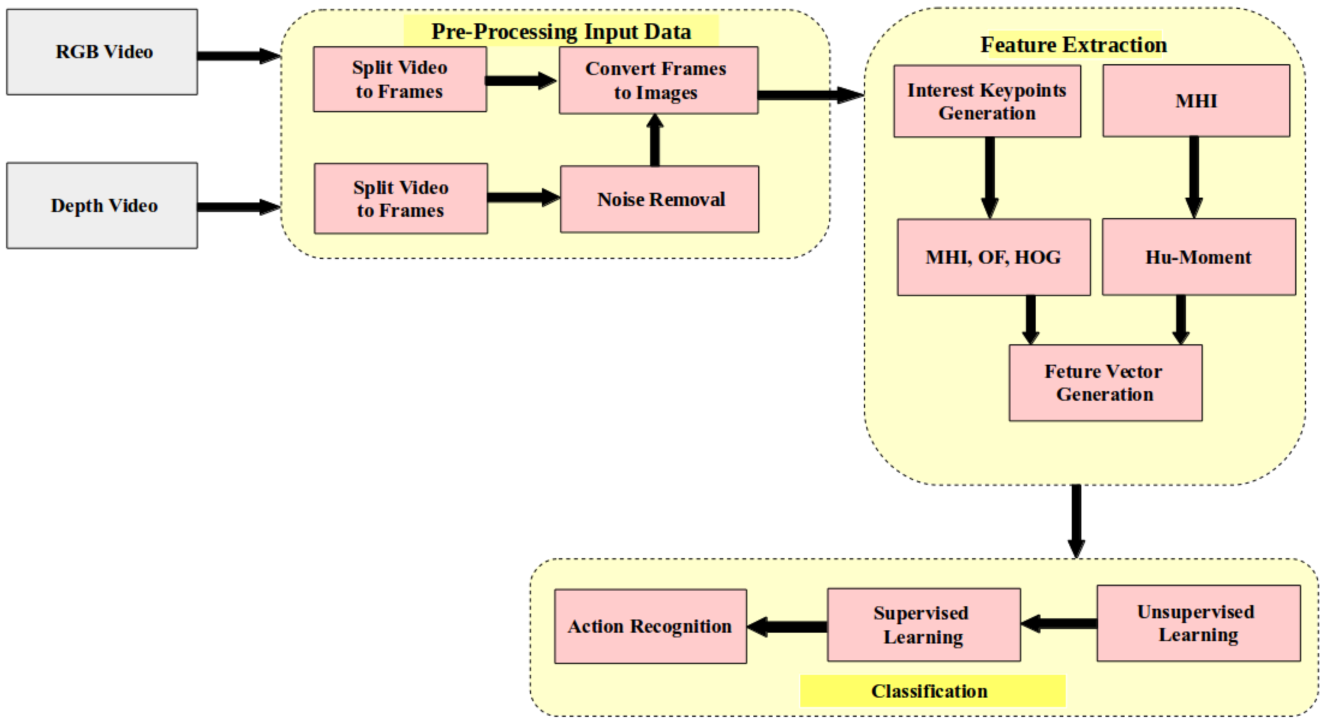

Fig. 2. System analysis schematics of action recognition. Using RGB and depth stream. Pre-processing to the input data; feature extraction; and classification.

Kinect infrared light reflections. For reducing noise and to eliminate the unmatched edges from the depth images, we used a spatial-temporal bilateral filtering to smooth depth images. The joint-bilateral filtering proposed in [20] is formulated as in (1):

$$\hat{D}_{(P)} = \frac{1}{K_{(p)}} \sum_{q \in \Omega_p} f(p,q) g(\| \hat{D}_m(p) - \hat{D}_m(q) \|) \\ h(\| I_{(p)} - I_{(q)} \|) \tag{1}$$

Where, $f(p,q)$ refers to the domain term for measuring the closeness of the pixels, p, and q. the function $g(.)$ denotes a depth range term that computes the pixel similarity of the modeled depth map. $h(.)$ is function represent an intensity term to measure the intensity similarity. Moreover, Ω_p represents the spatial neighborhood of position p.

B. Bag of Features Extraction

For feature extraction, we flow the Bag-of-Features (BoFs) method, it is the most popular technique of feature representation for videos to learn and recognize the different human actions. The local features have been computed from the spatial-temporal domain by implementing the feature detector and descriptor methods on 3D data. The procedure for extracting features vectors include three steps: Interest keypoint generation, feature vector generation, and dictionary generation.

1) Interest Keypoints Generation: As the essential, we finding the motion interest points (keypoints) from RGB frame sequence using the Speed-Up Robust Features (SURF) detector [21] as a first step to extract visually distinctive keypoints from spatial domain. Then, these keypoints are filtered by using temporal (motion) template approach for detecting motion and computing its direction, this constraint from motion history images MHI that is generated by computing the difference between two adjacent frames as represented in [11], [22]. Those points with larger intensities in MHI representing the moving object with more recent motion. After that compute optical flows of those keys preserved after MHI filtering using the Lucas-Kanade method [23].

To represent how motion the image is moving, form a motion-history image (MHI). In an MHI H , the pixel intensity, which is represent a function of the temporal motion history that point. The MHI shown in (2) is formally defined as in [11].

$$H_\tau(x,y,t) = \begin{cases} \tau, & \text{if D(x,y,t)=1} \\ \max(0, H_\tau(x,y,t-1)-1) & \text{otherwise.} \end{cases} \tag{2}$$

Where, $D(x,y,t)$ is a binary image of differences between frames and τ is the maximum duration of motion. τ is the duration which decides the temporal extent of the movement (e.g., in terms of frames). After Computing the motion keypoints $P(x,y,t)$ from RGB images, this motion points are aligned to the related depth images $P_d(x,y,z,t)$, where (x,y,t) denote the coordinates and time of interest point p on RGB images and (x, y, z, t) refer to the 3D coordinate and time of interest point on depth images.

2) Feature Vector Generation: In order to represent the shape, appearance and motion information, we used two different descriptors. HOG features descriptor [7] is applied on both RGB and depth video frames and combined feature vector values to generate the BoFs. This descriptor is widely used in human detection [24] and action recognition [25]. For vector generation, the HOG descriptor was implemented around each keypoints in video frames of RGBD images, MHI and OF channel and also, can be well adapted to characterize local shape information from image channel and local motion information from MHI channel by computing distributions of local gradients. Seven Hu-moment shape features are extracted from MHI that computed above in (2). For two-dimensional (MXM) images that has MHI function $f(x, y); x, y = 0, 1, ..., M-1$, geometric moment m_pq of $f(x, y)$ is computed as follows [26]:

$$m_{pq} = \sum_{x=0}^{x=M-1} \sum_{y=0}^{y=M-1} (x)^p.(y)^q f(x, y), \tag{3}$$

for $p, q = 0, 1, 2, 3, ..,$, where p, q are positive integers and $(p + q)th$ is called the order of the moment of a density distribution function $f(x, y)$.

The moments value of $f(x, y)$ are translated by a quantity (a, b), which is computed as:

$$\mu_{pq} = \sum_x \sum_y (x + a)^p.(y + b)^q f(x, y), \tag{4}$$

Then, to make these moments invariant to translation, the central moment μ_{pq} can be defined from (4) as follows, by changing the values $a = -\bar{x}$, and $b = -\bar{y}$:

$$\mu_{pq} = \sum_x \sum_y (x + \bar{x})^p.(y + \bar{y})^q f(x, y), \tag{5}$$

Where,

$$\bar{x} = \frac{m_{10}}{m_{00}}, \bar{y} = \frac{m_{01}}{m_{00}}$$

And the scaling invariance of central moment can be computed by normalizing the moments of the scaled image by the scaled energy of the original image to become invariant to scale change, which can be defined as stated below.

$$\eta_{pq} = \frac{\mu_{pq}}{\mu^{\gamma}{}_{00}}, \gamma = \frac{p+q}{2} + 1 \tag{6}$$

Where, γ is the value of normalization factor.

The values of η_{pq} represented a set nonlinear function that calculated by normalizing central moments, which are invariant to object rotation, translation, position and scale change. The seven Hu-moments is derived as in (7) [26], [27]:

$$\begin{aligned}
M_1 &= \eta_{20} + \eta_{02}, \\
M_2 &= (\eta_{20} - \eta_{02})^2 + 4\eta_{11}^2, \\
M_3 &= (\eta_{30} - 3\eta_{12})^2 + (3\eta_{21} - \eta_{03})^2, \\
M_4 &= (\eta_{30} + \eta_{12})^2 + (\eta_{21} + \eta_{03})^2, \\
M_5 &= (\eta_{30} - 3\eta_{12})(\eta_{30} + \eta_{12})[(\eta_{30} + \eta_{12})^2 - 3(\eta_{21} + \eta_{03})^2] \\
&\quad +(3\eta_{21} - \eta_{03})(\eta_{21} + \eta_{03})[(\eta_{30} + \eta_{12})^2 + (\eta_{21} + \eta_{03})^2], \\
M_6 &= (\eta_{20} - \eta_{02})[(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2] + \\
&\quad 4\mu_{11}(\eta_{30} + \eta_{12})(\eta_{21} + \eta_{03}), \\
M_7 &= (3\eta_{21} - \eta_{03})(\eta_{30} + \eta_{12})[(\eta_{30} + \eta_{12})^2 - 3(\eta_{21} + \eta_{03})] + \\
&\quad (\eta_{30} - 3\eta_{12})(\eta_{21} + \eta_{03})[3(\eta_{30} + \eta_{12})^2 - (\eta_{21} - \eta_{03}^2]
\end{aligned} \tag{7}$$

Where, the numerical values of M_1 to M_6 are very small. To avoid precision problems the logarithms of the absolute values of these six functions, i.e. $log|M_i|$; where, $i = 1, .., 6$, are selected as features representing the action among video frames.

Finally, the feature vectors are generated by combining the hu-moment features with the HOG features to represent the action information from each RGBD video.

3) Dictionary Generation: After extracting features information from all RGBD video depending on the detector and descriptor strategy, the dictionary is generated from these feature vectors – this is the important step on (BoFs) method. The Dictionary was generated by clustering using the k-means algorithm as represented in Fig. 3. The size of the dictionary is important for the recognition process because if the size of the dictionary is set too small then the BoF model cannot express all the keypoints and if it is set too high then it might lead to over-fitting and increasing the complexity of the system [28]. The K-means clustering was applied on all BoF from training videos, the k is represents the dictionary size. The centroids of each cluster are combined to make a dictionary. In this method, we got the best result with a value of $k = 400$ as a dictionary size.

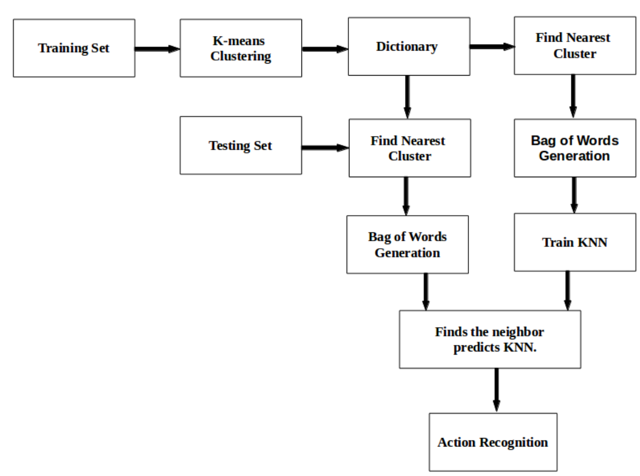

Fig. 3. Dictionary generation from feature vector for classified action.

C. Bag of Words Generation

In order to generate the Bag-of-Words (BoWs), each feature description of the video frame is compared with each centroid of the cluster in the dictionary using Euclidean distance measure e as formulated in (8) [29].

$$e = \sum_{j=1}^{k} \sum_{i=1}^{n} \|X_i{}^{(j)} - C_j\|^2 \tag{8}$$

Where, $\|X_i{}^{(j)} - C_j\|^2$ is the selected distance measure between the feature vector point and the clustering center C_j. C_j is the clustering center length and n is the feature vector size. Then, we check the difference e, if the difference is small or features values is close to a certain cluster, the count of that index is increased. Similarly, the other feature description of video frames are also compared and the counts of the respective indices are increased of which the feature description values are closest to as in [28]. These BoWs vectors are computed for all the videos for training and testing dataset.

D. Action Classification

In order to make performance comparison for our system, a k-nearest neighbor (KNN) is used. KNN is the simplest and mostly used classifier. It is assigned an object to a class according to the vote of its K-nearest neighbors, i.e. KNN is to classify unlabeled observations by assigning them to the class of the most similar labeled examples. Characteristics of observations are collected for both training and test dataset. K is an integer value and typically small and varied by the amount of test class. If K=1, the object is directly assigned to the class of its nearest neighbor.

In this work, the Bag of words vectors for all the videos is computed in training stage and labels are appended according to the class. This bag of words vectors are fed into the multi-class KNN in order to train the model that is further used in testing stage for human action recognition as shown in Fig. 3.

IV. EXPERIMENTATION AND EVALUATION

In this section, we present the two types of datasets used and the experimental results on them using our approach.

A. Dataset

To evaluate the performance of our system approach, we conducted experiments on the MSR DailyActivity 3D Dataset [1] and Online RGBD Action dataset (ORGBD), [2].

1) MSR-DailyActivity3D dataset: The MSR DailyActivity 3D Dataset is a daily activity dataset captured by a Kinect device and it is designed to cover humans daily activities in the living room [30]. This dataset contains 16 action and 10 subjects; each subject performs each activity in two different poses: *drinking, eating, read a book, call cell phone, writing on a paper, using laptop, using vacuum cleaner, cheer up, sitting, still, tossing paper, playing game, laying down on sofa, walking, playing guitar, stand up, and sit down* (see Fig. 4).

[1] http://www.uow.edu.au/~wanqing/#MSRAction3DDatasets
[2] https://sites.google.com/site/skicyyu/orgbd

2) Online RGBD Action Dataset: The Online RGBD Action dataset (ORGBD) [31] are captured by the Kinect device. Each action was performed by 16 subjects for two times. This dataset contains seven types of actions which recorded in the living room: *drinking, eating, using a laptop, picking up a phone, reading phone (sending SMS), reading a book, and using a remote* as shown in Fig. 5. We compare our approach with the state-of-the-art methods on the same environment test setting, where half of the subjects are used as training data and the rest of the subjects are used as test data.

Fig. 4. Sample frames of MSR-daily action 3D dataset.

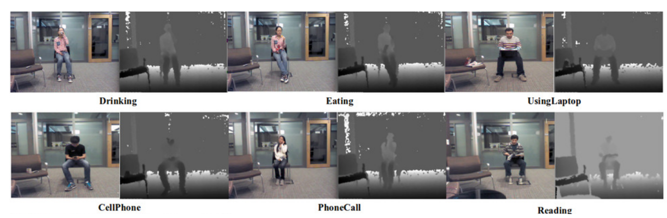

Fig. 5. Sample frames of online RGBD action dataset.

B. Experimental Results

In our experiments, we are combined two different feature descriptor information. The local features which encode information regarding all the available modalities and the shape invariant moment. The local features are extracted as follows: From RGB videos, the SURF detector is used on spatial domains and filtered these points by MHI and OF on temporal domains to extract the motion points all video frames and then aligned these points to the depth sequences to get the RGBD interest motion points as in Fig. 6, which shows the position of interesting motion points in the video frames.

After that the local appearance and motion features are characterized by grids of the histogram of orientation gradient (HOG) [7] around the motion interest points. Normalized histograms of all the patches are concatenated into HOG (for appearance features in the intensity image), HOG-MHI (for motion features in the MHI) and HOG-OF (for motion features

TABLE I. COMPARISON OF RECOGNITION ACCURACY WITH OTHER METHODS ON MSR-DAILYACTIVITY 3D DATASET

Methods	Accuracy
CHAR [32]	54.7%
Discriminative Orderlet [31]	60.1%
Relative Trajectories 3D [33]	72.00%
Moving Pose [34]	73.80%
Proposed Method	**100%**

TABLE II. COMPARISON OF RECOGNITION ACCURACY WITH OTHER METHODS ON ONLINE RGBD (ORGBD) DATASET

Methods	Accuracy
HOSM [35]	49.5%
Orderlet+SVM [31]	68.7%
Orderlet+ boosting [31]	71.4%
Human-Object Interaction[36]	75.8%
Proposed Method	**85.71%**

in the OF) descriptor vectors as the input of the classifier for action recognition.

In this test, we set x and y equal to 3 and use 6 bins for HOG in the intensity image, HOG-MHI, and HOG-OF. These selected values are applied on RGB and Depth channels.

Fig. 6. Motion points in RGB and depth frames of different action represented by green points on RGB frame and white points on depth frames.

The Hu-moment features are computed from MHI channel on both RGB and depth video frames to compute the seven invariant features from each frame in video. The last step in computing features vector is combined the local and hu-moment feature to represent the feature vector. All testing results of the experiment are described on Tables I and II, which shows the comparison results of recognition rate of our system test and the other state of the art using different methods of the MSR-DailyAction 3D datasets and ORGBD Dataset, respectively.

V. CONCLUSION AND FUTURE WORKS

In this paper, a human action recognition on 3D video (RGB and Depth data) is proposed. Our system starts from processing, removing the noise from the input depth data and aligning the RGB with the depth frames. We proposed two sets of feature information, which are represented by the local feature vector by extracting these features from 3D video data using SURF, MHI, and OF for detecting motion interest points, and for the appearance and motion features, the HOG descriptor is applied on image, MHI and OF of each RGB and depth video of all actions and the other feature set is extracted using global Hu-moments shape descriptor from MHI, then combined all motion, shape and appearance vectors into one vector for each RGBD video action. These feature vector values are tested depending on the Bag-of-words method (BoWs) by using k-means clustering and KNN classifier. The presented approach is highly efficient and invariant to cluttered backgrounds, illumination changes, rotation, translation and scale.

The Experiment results showed that the proposed scheme can effectively recognize the similar action with high movement rate as walking, cleaning, etc. and improves performance on actions with low movement rate like: reading, using laptop, etc. It gives a 100% on 3D MSR Daily action dataset and 85.71% on ORGBD dataset recognition rates. From this method on RGBD dataset demonstrate that our approach significantly outperforms the existing state-of-the-art methods. The best performance is achieved because interest points are extracted solely from the RGB channel and aligned to the depth, then combined the RGB and depth based descriptors values depending on this detected motion points.

For the future works, we will combine a new feature vector values like local binary pattern (LBP). Also for the classification task, the convolution neural networks (CNN), and random forest will be use.

ACKNOWLEDGEMENTS

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Analyzing the Diverse Impacts of Conventional Distributed Energy Resources on Distribution System

Muhammad Aamir Aman[1], Sanaullah Ahmad[1], Azzam ul Asar[2], Babar Noor[1]

[1]Electrical Engineering Department, IQRA National University, Peshawar, Pakistan
[2]Electrical Engineering Department, CECOS University, Peshawar, Pakistan

***Abstract*—In recent years, the rapid boost in energy demand around the globe has put power system in stress. To fulfill the energy demands and confine technical losses, researchers are eager to investigate the diverse impacts of Distributed Generation (DG) on the parameters of distribution network. DG is becoming even more attractive to power producing companies, utilities and consumers due to production of energy near to load centers. Reduction in power losses, better voltage profile and less environmental impact are the benefits of DG. Besides renewable energy resources, conventional energy resources are also a viable option for DG. This research aims to analyze the impact of localized synchronous and induction generators on distributions network. The main objectives are to find optimal type, size and location of DG in distribution network to have better impact on voltage profile and reduction in power losses. Using worldwide recognized software tool ETAP and Kohat road electricity distribution network as a test case. Results depicted that at certain buses, positive impacts on voltage profile were recorded while almost 20% of power losses were decreased when synchronous generator as DG unit was injected in distribution network. Injecting induction generator as DG unit, the results showed increase in power losses due to absorption of reactive power, while improving voltage profile by injecting active power.**

Keywords*—Electric power system; distributed generation; voltage profile; power losses; synchronous generator; induction generator

I. Introduction

In electrical power plants the power is generated which fulfill the demand of energy required. The capacity of generation depends on type and size of the generating unit. Capacities of these traditional power plants vary from hundreds of Megawatt to few Gegawatt [1]. These generation power plants of such a large scale are placed far away from load centers. For transmission of power from the generation station to the customer's premises transmission lines and distribution feeders are used [2], [3]. As shown in Fig. 1, it is necessary for the utilities to provide standard voltage profile/level to its customers.

To balance demand and supply gap, DG became the feasible option. The term DG can be defined as any power generation unit that is integrated within the distributed system [4]. DG may be a conventional or non conventional energy source which consists of wide range of technologies such as internal combustion engines which are prime movers for synchronous and induction generators, wind turbines, photo voltaic systems, fuel-cells, etc. For generation of power if DG

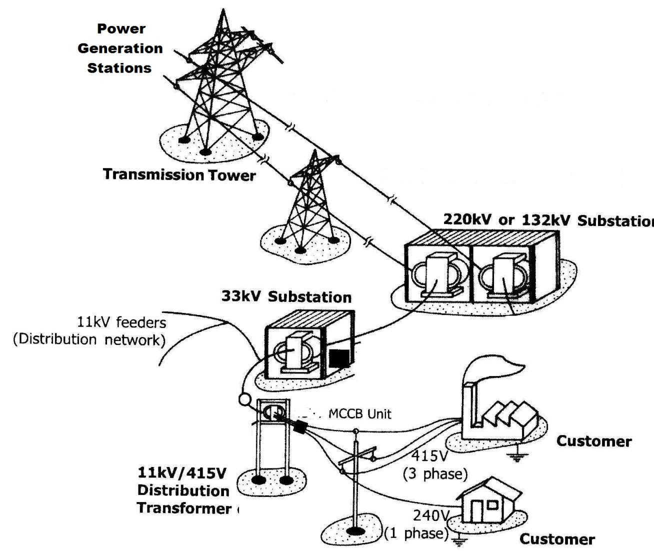

Fig. 1. Traditional power system.

uses non-conventional or renewable energy sources then it is known as renewable distributed generation as shown in Fig. 2 [4].

DG typically ranges from few Kilowatts (KW) to several Megawatts (MW) as they are not centralized [1]. Both conventional (non-renewable) and non-conventional (renewable) resources can be used to generate power for DG [3]. Combustion engines and fuel cell are used as conventional energy resources, while geothermal system, solar energy and wind energy are used as non-conventional energy resources [5]. DG sources accompanied with energy storage technologies is called distributed source of energy as shown in Fig. 2.

As DG is on site generation of power feeding to the distribution network, to acquire a complete and reliable DG system it is more important to have the knowledge of injecting DG at proper optimal location and to determine the source of DG either renewable or non-renewable and also number of DG units. Connection and process of power generation elements linked straightly to distribution system or associated to the network on consumer's location of the meter defines the location of distributed generation [6], [7].

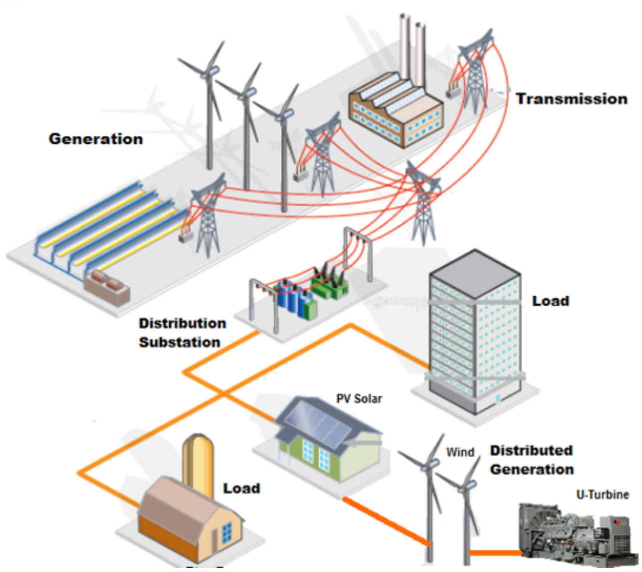

Fig. 2. Localized power distributed generation.

DG is the power generation from the resources which is not centralized and is injected in the distribution system near the load centers. While the traditional power system is linked to the main grid, contains the generation station, transmission network and distribution system. In distribution system voltage and reactive power control equipment, in a current grid system are mostly operated on unidirectional power flow only, that is from the transmission system to high voltage and medium voltage substations and then to the low voltage distribution system. Thus there is decrease in voltage along the feeder, from the substation to the feeder-end. By installing DG makes this statement no longer valid. When DG is injected it will affect voltage profile. Also, when the output power of DG is high then the power may flow from the distribution system to the transmission system which may start false trigging of protection system [8].

DG unit to be effectively is desirable to operate at full capacity. But if they are injected improperly causes restriction and limits its maximum capacity. So, to have undesirable effects on the power system DG unit must be placed at optimal location to operate to its maximum limit [9]. Researchers are eager to develop methods and algorithms to achieve adequate voltage profile and reduce power losses by optimization of DG.

To manage the increasing demand of power and to reduce line losses and voltage profile, DG is considered to be a power paradigm for the new millennium. This depends on optimal location of DG injection and also type of DG to be injected in the power system. If DG is injected in a power system in un-deterministic way a vital impact of DG occurs, causing variation in voltage profile and power losses. Utility companies are searching for a technique to provide standard voltage to the customer's premises. Injection of DG at optimum location is one solution to overcome this problem.

In this paper Electrical Transient Analyzer Program (ETAP) software tool is used for simulation and analysis. This paper focuses on the impact of DG on voltage profile and power losses in a radial test system in which three cases are considered: firstly results are evaluated when no DG unit is injected, secondly and foremost impact of synchronous generator and induction generator as a DG units are evaluated and lastly comparison for optimum type and location of DG is carried out.

II. Distributed Generation and its Diverse Impact on Distribution System

Universally DG is accepted as an effective and economical solution to reduce the increasing demand in power system. In current years, DG achieved much consideration due to its positive impacts on the electrical distribution systems. Some of these are improving transmission and distribution congestion, voltage and power quality, line losses reduction, reliability, power consumption demand, security, and reaching the goal to utilize green and renewable energy resources [10], [11]. Also DG has lesser principal cost because of utilizing renewable energy resources and has nil pollutant radiations. DG can work in the situation of peak shaving during increase in requirement and also as a backup in case of interruption.
However, some negative impacts of DG including voltage rise, poor power quality , harmonics, etc. Absence of synchronization between DGs and distribution system results in voltage regulation problems [12].

A. Impact of DG on Voltage Profile and Power Losses

For positive impacts, DG must be appropriately synchronized with the operational system and feeder scheme. This means addressing concerns allied to voltage regulation, flicker, grounding compatibility, overcurrent safety, harmonic variations, consistency, islanding, capability limits and further aspects. Integration of DG and its impact on system is relative to feeder demand and capacity therefore the coordination of DG with system must be optimized accurately to avoid these issues [13].

It is of prodigious significance to clients having a better voltage profile because its an elementary request for electrical equipment running near the valued voltage. Voltage drop may occur across the distribution transformer due to line impedance, line losses, etc. Thus, rated voltage at customer service would change.

DG supports the voltage to rise at the termination of the feeder. Though, where the DG is introduced may raise the voltage above the standard limits. Voltage may be greater at the consumer amenities than on the primary side of the distribution transformer and may even go beyond the voltage above the higher limits. It means that both high and low service voltage can take place due to the mismatch of DG with the radial power stream.

III. Power Flow Analysis and Mathematical Modeling

The electrical network is signified by non-linear algebraic equations under steady state. Power flow solution uses these equations. For determining the simultaneous equations iterative methods are used. Different methods are used for solving Gauss-Seidel approach is discussed below.

A. Power Flow Solution by Gauss-Seidel Method

Gauss-Seidel is one of the iterative methods used for solving non-linear algebraic equations. Complex voltage at every node successively sweeps and updates its neighbor bus voltage in this arrangement.

$I_{Bus}=Y_{Bus} x V_{Bus}$

And for any particular Bus "a"

$I_a= \sum_{n=1}^{N} Y_{an} V_n$

The complex power

$S_a = V_a I_a{}^*$

$P_a + jQ_a = V_a[\sum_{n=1}^{N} Y_{an} V_n]^*$

Where a = 1, 2, 3 ...N

For complex power

$I_a=\frac{P_a + jQ_a}{V_a^*}$

Also, $I_a=\sum_{n=1}^{N} Y_{an} V_n$

Or,

$$I_a = Y_{a1}V_1 + Y_{a2}V_2 + \cdots\cdots + Y_{aa}V_a + \cdots\cdots + Y_{aN}V_N \quad (1)$$

From the above equation

$$V_a = \frac{1}{Y_{aa}[I_a - (\sum_{n=1}^{a-1} Y_{an}V_n + \sum_{a+1}^{N} Y_{an}V_n)]}$$

or,

$$V_a = \frac{1}{Y_{aa}[\frac{P_a+jQ_a}{V_a^*} - (\sum_{n=1}^{a-1} Y_{an}V_n + \sum_{a+1}^{N} Y_{an}V_n)]}$$

Where, a = 1, 2, 3... N

However, suitable determination is desired at per iteration, with proliferation in number of iterations the tolerance reduces because the convergence of this technique is linear. This postures important restriction for large system because of the solution time and estimation cost increases.

B. Gauss-Seidel Iterative Procedure

1) Make an initial guess $| V_i |= 1.0$ and $\delta_{i(0)} = 0.00$.

2) Use this solution in power flow equation to obtain the better first solution and this solution is called improved estimated of V_a.

3) First solution is used to obtain a better second solution and so on, in general equation i.e.

$$V_a^{i+1} = \frac{1}{Y_{aa}[\frac{P_a+jQ_a}{V_a^{i*}} - (\sum_{n=1}^{a-1} Y_{an}V_n^{i+1} + \sum_{a+1}^{N} Y_{an}V_n^{i})]}.$$

IV. RESEARCH METHODOLOGY

For this research work a residential radial distribution feeder of 11KV located at Kohat Road Peshawar, Khyber Pakhtunkhwa, Pakistan is selected. The selected feeder is modeled and analyzed in Electrical Transient Analyzer Program (ETAP). ETAP software tool is used worldwide for power system planning, designing, operation and analysis.

V. MODELING OF DISTRIBUTED GENERATION UNITS

For this research work synchronous and induction generator are selected as a DG units. They will operate in different conditions.

A. Without Distributed Generation Unit

The analysis of the modeled feeder in ETAP will be done when no DG is injected. The results obtained from this case are taken as a reference. The results evaluated from other cases will be compared in order to analyze the impact of different type, size and location of DG on voltage profile and power losses.

B. Synchronous Generator as Distributed Generation Unit

Synchronous generator as DG unit of 2.5 MW will be modeled and will be placed at different buses in radial distribution system as shown in Fig. 3. The DG unit will inject only real power into the system with unity power factor. Two different places bus-3 and bus-6 are selected for connecting DG units randomly.

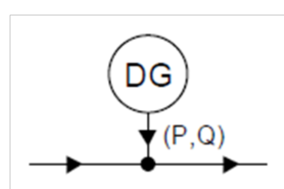

Fig. 3. Synchronous generator as DG.

C. Induction Generator as Distributed Generation Unit

An optimum size of 2.5 MW DG will be modeled and injected in the radial distribution system at bus-3 and bus-6 randomly as shown in Fig. 4. DG will inject active power and will absorb reactive power, working as an induction generator mode with an operating power factor of 0.85 lagging.

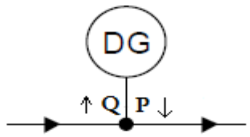

Fig. 4. Induction generator as DG.

VI. Test Cases

In this research work the following different cases have been conducted:

A. Case-I

Load flow analysis of the radial distribution network in case-I is shown in Fig. 5. The requirement of load is fulfilled by the power grid as in this case no DG unit is injected. This case is taken as a reference for other cases. Real time condition and voltage levels at different buses are shown. As the red color shows critical condition of buses, bus-5 and bus-6 are in critical condition in this case.

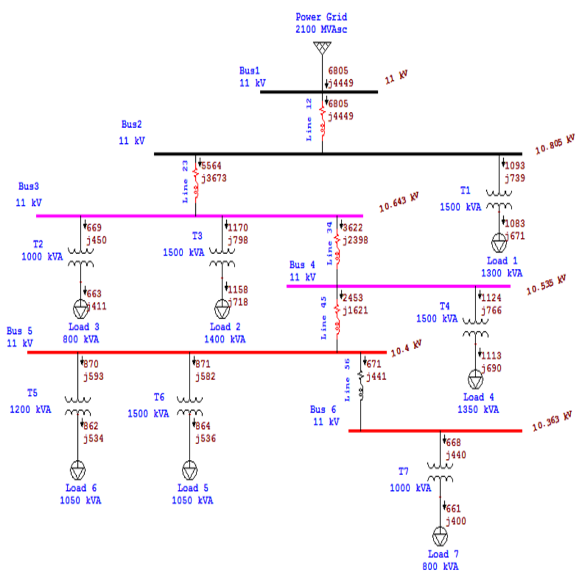

Fig. 5. Without DG unit.

Power losses at distribution transformers and different lines of distribution network are shown in Table I. In this case the total active power losses are 399.7 KW and reactive power losses are 489.9 KVAR.

B. Case-II

Load flow analysis of Case-II while injecting DG at bus-3 are shown in Fig. 6. DG unit of 2.5 MW connected with the system at Bus-3 operating at power factor of unity. Requirement of load is fulfilled by the power grid and DG source mutually in this case. By comparing voltages with previous case voltage level is improved at different buses as shown in Fig. 6.

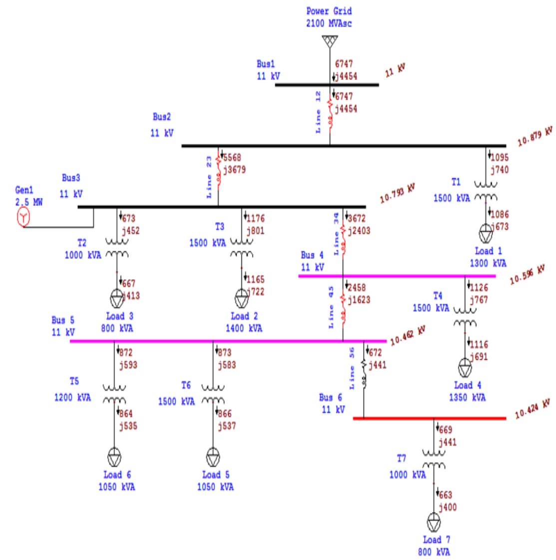

Fig. 6. DG unit connected at bus-3.

The power losses at different locations in distribution network are shown in Table II. These losses are decreased from the previous case when no DG was connected as the total active power losses are 321.3 KW while the total reactive power losses are 481.8 KVAR.

C. Case-III

The load flow analysis of Case-III are shown in Fig. 7. A DG unit of 2.5 MW is connected at Bus-6 operating at power factor of 0.85 lagging. Requirements of load is fulfilled by the power grid and DG source mutually. While real power is injected in the system and reactive power is absorbed from the system by the DG unit as connected DG unit is induction generator.

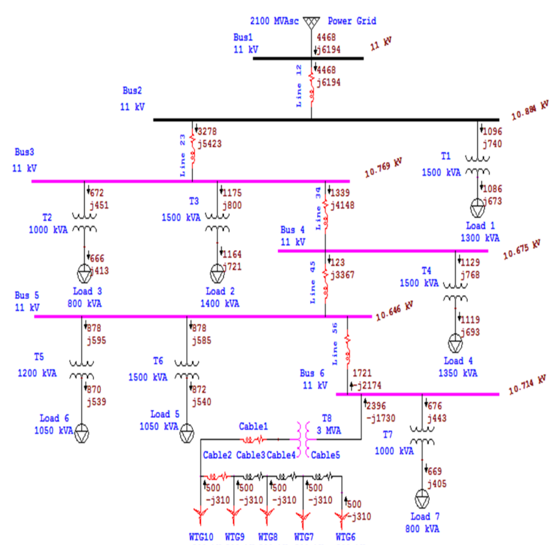

Fig. 7. DG unit of 2.5 MW connected at bus-6.

TABLE I. CASE-I TOTAL POWER LOSSES OF THE SYSTEM

Branch/ Circuit ID		Line 12	Line 23	T1	Line 34	T2	T3	Line 45	T4	Line 56	T5	T6	T7	Total
Losses	KW	147.8	103.0	9.7	45.1	6.3	11.4	41.2	10.8	3.1	8.3	6.5	6.5	399.7
	KVAR	37.4	26.1	67.8	11.4	39.1	80.6	6.1	75.9	0.5	58.3	46.2	40.6	489.9

TABLE II. CASE-II POWER LOSSES DUE INJECTION OF DG UNIT AT BUS-3

Branch/ Circuit ID		Line 12	Line 23	T1	Line 34	T2	T3	Line 45	T4	Line 56	T5	T6	T7	Total
Losses	KW	83.6	47.5	9.6	87.4	6.2	11.2	40.9	10.7	3.1	8.2	6.5	6.4	321.3
	KVAR	35.1	23.5	67.2	12.9	38.4	79.1	6.0	75.3	0.5	57.8	45.8	40.2	481.8

The power losses at different locations in distribution network are shown in Table III. When an induction generator unit is connected at bus-6 the total power losses i.e. active power losses and the total reactive power losses are 522.8 KW and 660.9 KVAR, respectively, as comparing to DG unit placement at Busbar-3 these losses are increased as shown in Table III.

VII. RESULTS AND DISCUSSIONS

This section discusses the results calculated after the implementation of above cases. Table IV shows a detail report about the real and reactive power injected by DG unit and by grid in each case. The DG unit acts as a negative load when injected in the system.

A. Voltage Profile Analysis

Different impacts on voltage profile occurs when different types of DG unit are connected with the radial distribution system. Table V shows the overall results.

1) Case-I: In this case no DG unit is injected with the system. Fig. 8 shows the radial decrease in voltage profile from source to load. This reduction in voltage level is due to the line impedance.

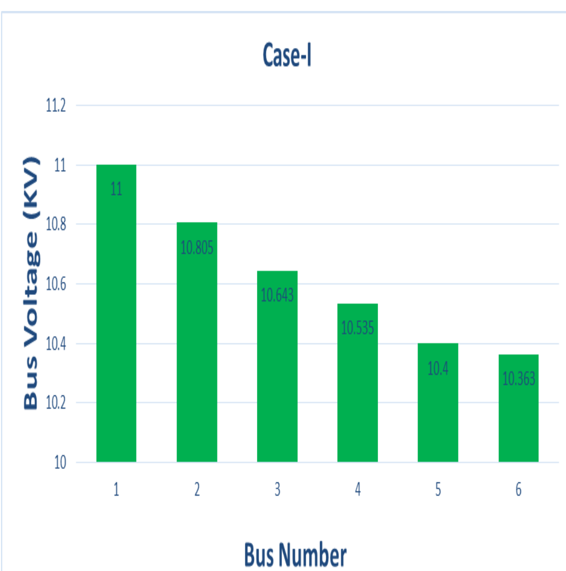

Fig. 8. Radial feeder voltage arrangement.

2) Case-II: 2.5 MW DG unit is installed in this case at Bus-3. Operating power factor of this DG unit is unity. Injection of DG unit is considerable effects on voltage profile. Voltage profile is improved in this case. This case shows the best results as comparing it to the other cases. As depicted in Fig. 9.

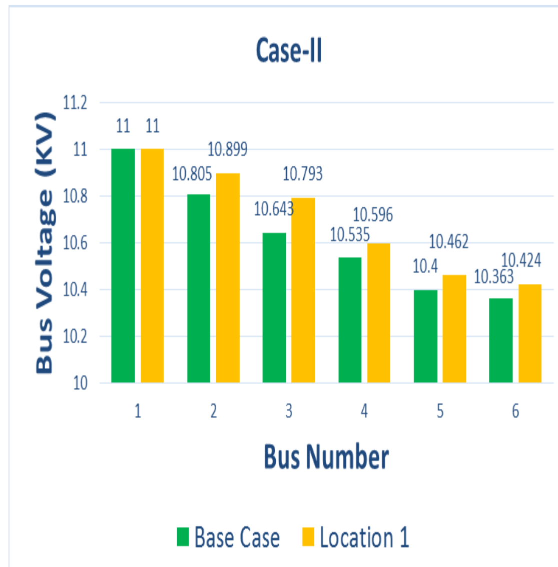

Fig. 9. Impact on voltage profile when active power is injected.

3) Case-III: In this case 2.5 MW capacity of DG unit is injected to the system delivering active power while absorbing reactive power. The result obtained from injection of DG unit at Busbar-6 is shown in the Fig. 10.

The results obtained from injecting synchronous generator at bus-3 are far better than injecting induction generator at bus-6.

B. Power Loss Analysis

1) Case-I: No DG unit is injected with the radial distribution network in this case. The total power losses of the system are shown in Fig. 11. These losses occur due to line impedances. These losses also consist of some fixed losses which are constant and cannot be changed e.g. transformer losses. There is no DG unit installed in this case and the total power is fed from the power grid. Current flow from the power grid to the consumer localities through each cable results in huge amount of power losses.

TABLE III. CASE-III POWER LOSSES DUE TO INJECTION OF DG UNIT AT BUS-6

Branch/ Circuit ID		Lines Total	Transformers Total	Cables Total	Total
Losses	KW	360	73.9	88	522.8
	KVAR	80.3	567.5	12.9	660.9

TABLE IV. INJECTION OF REAL AND REACTIVE POWER FROM DG UNITS AND GRID

Case	DG Injected Power		Grid Injected Power	
	MW	MVAR	MW	MVAR
1	0	0	6.805	4.449
2	2.5	0	6.747	4.454
3	2.5	-1.55	4.468	6.194

TABLE V. DIFFERENT BUSES VOLTAGE LEVELS

No. of Bus	Case-I	Case -II	Case -III
1	11	11	11
2	10.805	10.899	10.884
3	10.643	10.793	10.769
4	10.535	10.596	10.675
5	10.4	10.462	10.646
6	10.363	10.424	10.714

2) Case-II: 2.5 MW DG unit injecting active power and power grid mutually fed the load and hence reduces the power losses as shown in Fig. 12. It is clearly seen that losses are reduced by the installation of DG unit.

3) Case-III: 2.5 MW induction generator is injected as a DG unit in this case. This DG setup is delivering active power while absorbing reactive power from the system. The losses in this case are increased from the base case as shown in Fig. 13. The logic behind this increase in losses is that the induction generator absorbs reactive power from the system. It is noted that by injecting synchronous generator at busbar-3 shows the outperform results than by injecting induction generator as a DG in busbar-6. Therefore, injecting DG unit at optimum location i.e. busbar-3 and DG type i.e. synchronous generator will give greater reduction in power losses.

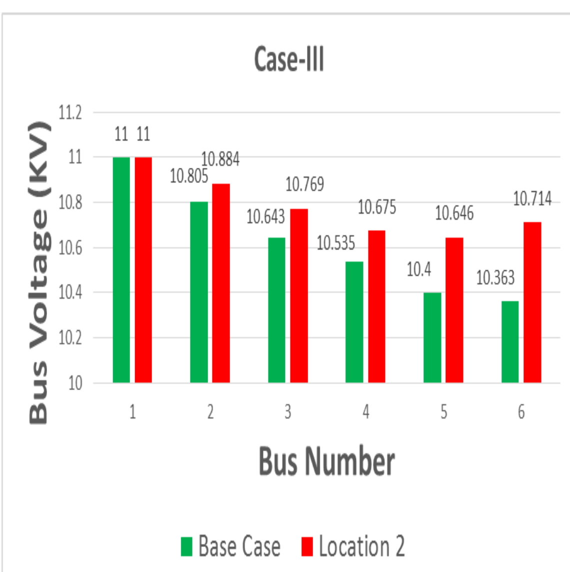

Fig. 10. Induction generator impacts on voltage profile.

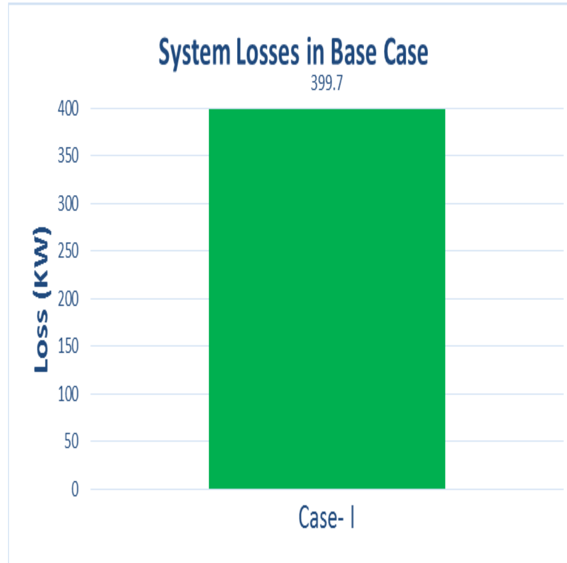

Fig. 11. Total active power losses of the radial distribution system.

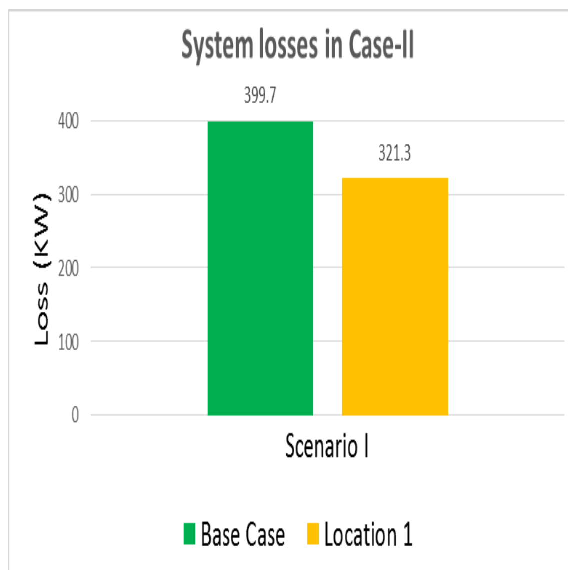

Fig. 12. Power losses of the system in case of active power injected by DG unit.

VIII. CONCLUSION AND FUTURE WORK

Analyzing the assorted impacts of DG units on distributed system is of most significance. Some vital factors such as type, size and location of DG units are important for proper utilization of DG units. The detailed analysis in this research work showed diverse impacts of DG on voltage profile and power losses. It is investigated that connecting synchronous generator as a DG unit near to load centers will improve voltage profile and reduce power losses. While connecting induction generator

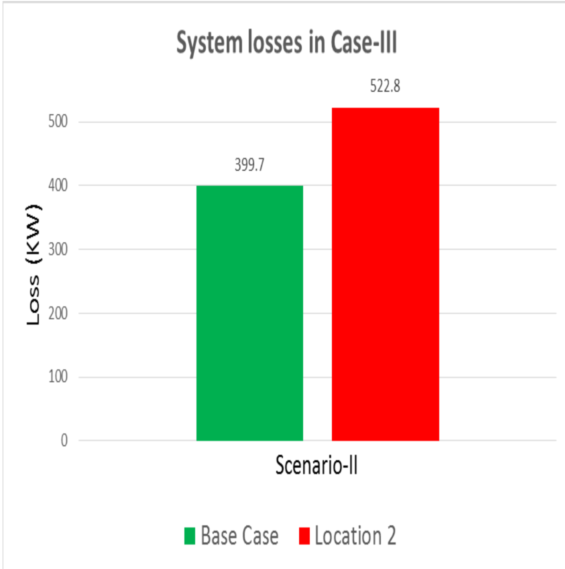

Fig. 13. Power losses of the system in case of injecting induction generator as a DG unit.

as DG unit near to load centers have positive impact on voltage profile but it caused increase in power losses due to absorption of reactive power by induction generator. In future several DG technologies either conventional or non-conventional, can be evaluated for their various impacts on distribution system.

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Text Summarization Techniques: A Brief Survey

Mehdi Allahyari*, Seyedamin Pouriyeh†, Mehdi Assefi†, Saeid Safaei†, Elizabeth D. Trippe‡,
Juan B. Gutierrez‡, Krys Kochut†
*Department of Computer Science, Georgia Sothern University, Statesboro, USA
†Department of Computer Science, University of Georgia, Athens, USA
‡Department of Mathematics Institute of Bioinformatics University of Georgia Athens, USA

***Abstract*—In recent years, there has been a explosion in the amount of text data from a variety of sources. This volume of text is an invaluable source of information and knowledge which needs to be effectively summarized to be useful. Text summarization is the task of shortening a text document into a condensed version keeping all the important information and content of the original document. In this review, the main approaches to automatic text summarization are described. We review the different processes for summarization and describe the effectiveness and shortcomings of the different methods.**

Keywords*—*Text summarization; extractive summary; abstractive summary knowledge bases; topic models

I. Introduction

With the dramatic growth of the Internet, people are overwhelmed by the tremendous amount of online information and documents. This expanding availability of documents has demanded exhaustive research in the area of automatic text summarization. According to Radef et al. [1] a *summary* is defined as "a text that is produced from one or more texts, that conveys important information in the original text(s), and that is no longer than half of the original text(s) and usually, significantly less than that".

Automatic text summarization is the task of producing a concise and fluent summary while preserving key information content and overall meaning. In recent years, numerous approaches have been developed for automatic text summarization and applied widely in various domains. For example, search engines generate snippets as the previews of the documents [2]. Other examples include news websites which produce condensed descriptions of news topics usually as headlines to facilitate browsing or knowledge extractive approaches in different domains [3]–[6].

Automatic text summarization is very challenging, because when we as humans summarize a piece of text, we usually read it entirely to develop our understanding, and then write a summary highlighting its main points. Since computers lack human knowledge and language capability, it makes automatic text summarization a very difficult and non-trivial task.

Automatic text summarization gained attraction as early as the 1950s. An important research of these days was [7] for summarizing scientific documents. Luhn et al. [7] introduced a method to extract salient sentences from the text using features such as *word* and *phrase frequency*. They proposed to weight the sentences of a document as a function of high frequency words, ignoring very high frequency common words. Edmundson et al. [8] described a paradigm based on *key phrases* which in addition to standard frequency depending weights, used the following three methods to determine the sentence weight:

1) *Cue Method*: The relevance of a sentence is calculated based on the presence or absence of certain cue words in the cue dictionary.
2) *Title Method*: The weight of a sentence is computed as the sum of all the content words appearing in the title and headings of a text.
3) *Location Method*: This method assumes that sentences appearing in the beginning of document as well as the beginning of individual paragraphs have a higher probability of being relevant.

Since then, many works have been published to address the problem of automatic text summarization (see [9], [10] for more information about more advanced techniques until 2000s).

In general, there are two different approaches for automatic summarization: *extraction* and *abstraction*. *Extractive summarization* methods work by identifying important sections of the text and generating them verbatim; thus, they depend only on extraction of sentences from the original text. In contrast, *abstractive summarization* methods aim at producing important material in a new way. In other words, they interpret and examine the text using advanced natural language techniques in order to generate a new shorter text that conveys the most critical information from the original text. Even though summaries created by humans are usually not extractive, most of the summarization research today has focused on extractive summarization. Purely extractive summaries often times give better results compared to automatic abstractive summaries [10]. This is because of the fact that abstractive summarization methods cope with problems such as semantic representation, inference and natural language generation which are relatively harder than data-driven approaches, such as sentence extraction. As a matter of fact, there is no completely abstractive summarization system today. Existing abstractive summarizers often rely on an extractive preprocessing component to produce the abstract of the text [11], [12].

Consequently, in this paper we focus on extractive summarization methods and provide an overview of some of the most dominant approaches in this category. There are a number of papers that provide extensive overviews of text summarization techniques and systems [13]–[16].

The rest of the paper is organized as follows: Section II describes the extractive summarization approaches. Topic representation methods are explained in Section III. Section IV details knowledge bases and automatic summarization. Section V explains the impact of context in the summarization task. Indicator representation approaches are described in Section VI. Finally, Section VII outlines the evaluation methods for summarization.

II. Extractive Summarization

As mentioned before, extractive summarization techniques produce summaries by choosing a subset of the sentences in the original text. These summaries contain the most important sentences of the input. Input can be a single document or multiple documents.

In order to better understand how summarization systems work, we describe three fairly independent tasks which all summarizers perform [15]: *1*) Construct an intermediate representation of the input text which expresses the main aspects of the text. *2*) Score the sentences based on the representation. *3*) Select a summary comprising of a number of sentences.

A. Intermediate Representation

Every summarization system creates some intermediate representation of the text it intends to summarize and finds salient content based on this representation. There are two types of approaches based on the representation: *topic representation* and *indicator representation*. *Topic representation* approaches transform the text into an intermediate representation and interpret the topic(s) discussed in the text.

Topic representation-based summarization techniques differ in terms of their complexity and representation model, and are divided into frequency-driven approaches, topic word approaches, latent semantic analysis and Bayesian topic models [15]. We elaborate topic representation approaches in the following sections. *Indicator representation* approaches describe every sentence as a list of features (indicators) of importance such as sentence length, position in the document, having certain phrases, etc.

B. Sentence Score

When the intermediate representation is generated, we assign an *importance score* to each sentence. In topic representation approaches, the score of a sentence represents how well the sentence explains some of the most important topics of the text. In most of the indicator representation methods, the score is computed by aggregating the evidence from different indicators. Machine learning techniques are often used to find indicator weights.

C. Summary Sentences Selection

Eventually, the summarizer system selects the top k most important sentences to produce a summary. Some approaches use greedy algorithms to select the important sentences and some approaches may convert the selection of sentences into an optimization problem where a collection of sentences is chosen, considering the constraint that it should maximize overall importance and coherency and minimize the redundancy. There are other factors that should be taken into consideration while selecting the important sentences. For example, context in which the summary is created may be helpful in deciding the importance. Type of the document (e.g. news article, email, scientific paper) is another factor which may impact selecting the sentences.

III. Topic Representation Approaches

In this section we describe some of the most widely used topic representation approaches.

A. Topic Words

The topic words technique is one of the common topic representation approaches which aims to identify words that describe the topic of the input document. [7] was one the earliest works that leveraged this method by using frequency thresholds to locate the descriptive words in the document and represent the topic of the document. A more advanced version of Luhn's idea was presented in [17] in which they used log-likelihood ratio test to identify explanatory words which in summarization literature are called the "topic signature". Utilizing topic signature words as topic representation was very effective and increased the accuracy of multi-document summarization in the news domain [18]. For more information about log-likelihood ratio test, see [15].

There are two ways to compute the importance of a sentence: as a function of the number of topic signatures it contains, or as the proportion of the topic signatures in the sentence. Both sentence scoring functions relate to the same topic representation, however, they might assign different scores to sentences. The first method may assign higher scores to longer sentences, because they have more words. The second approach measures the density of the topic words.

B. Frequency-driven Approaches

When assigning weights of words in topic representations, we can think of binary (0 or 1) or real-value (continuous) weights and decide which words are more correlated to the topic. The two most common techniques in this category are: *word probability* and *TFIDF* (Term Frequency Inverse Document Frequency).

1) Word Probability: The simplest method to use frequency of words as indicators of importance is *word probability*. The probability of a word w is determined as the number of occurrences of the word, $f(w)$, divided by the number of all words in the input (which can be a single document or multiple documents):

$$P(w) = \frac{f(w)}{N} \tag{1}$$

Vanderwende et al. [19] proposed the SumBasic system which uses only the word probability approach to determine sentence importance. For each sentence, S_j, in the input, it assigns a weight equal to the average probability of the words in the sentence:

$$g(S_j) = \frac{\sum_{w_i \in S_j} P(w_i)}{|\{w_i | w_i \in S_j\}|} \tag{2}$$

where, $g(S_j)$ is the weight of sentence S_j.

In the next step, it picks the best scoring sentence that contains the highest probability word. This step ensures that the highest probability word, which represents the topic of the document at that point, is included in the summary. Then for each word in the chosen sentence, the weight is updated:

$$p_{new}(w_i) = p_{old}(w_i)p_{old}(w_i) \tag{3}$$

This word weight update indicates that the probability of a word appearing in the summary is lower than a word occurring once. The aforementioned selection steps will repeat until the desired length summary is reached. The sentence selection approach used by SumBasic is based on the greedy strategy. Yih et al. [20] used an optimization approach (as sentence selection strategy) to maximize the occurrence of the important words globally over the entire summary. [21] is another example of using an optimization approach.

2) TFIDF: Since word probability techniques depend on a stop word list in order to not consider them in the summary and because deciding which words to put in the stop list is not very straight forward, there is a need for more advanced techniques. One of the more advanced and very typical methods to give weight to words is TFIDF (Term Frequency Inverse Document Frequency). This weighting technique assesses the importance of words and identifies very common words (that should be omitted from consideration) in the document(s) by giving low weights to words appearing in most documents. The weight of each word w in document d is computed as follows:

$$q(w) = f_d(w) * log\frac{|D|}{f_D(w)} \tag{4}$$

where $f_d(w)$ is term frequency of word w in the document d, $f_D(w)$ is the number of documents that contain word w and $|D|$ is the number of documents in the collection D. For more information about TFIDF and other term weighting schemes, see [22]. TFIDF weights are easy and fast to compute and also are good measures for determining the importance of sentences, therefore many existing summarizers [10], [21], [23] have utilized this technique (or some form of it).

Centroid-based summarization, another set of techniques which has become a common baseline, is based on TFIDF topic representation. This kind of method ranks sentences by computing their salience using a set of features. A complete overview of the centroid-based approach is available in [24] but we outline briefly the basic idea.

The first step is topic detection and documents that describe the same topic clustered together. To achieve this goal, TFIDF vector representations of the documents are created and those words whose TFIDF scores are below a threshold are removed. Then, a clustering algorithm is run over the TFIDF vectors, consecutively adding documents to clusters and recomputing the centroids according to:

$$\boldsymbol{c}_j = \frac{\sum_{d \in C_j} d}{|C_j|} \tag{5}$$

where $\boldsymbol{c}_j$ is the centroid of the jth cluster and C_j is the set of documents that belong to that cluster. *Centroids* can be considered as pseudo-documents that consist of those words whose TFIDF scores are higher than the threshold and form the cluster.

The second step is using centroids to identify sentences in each cluster that are central to topic of the entire cluster. To accomplish this goal, two metrics are defined [25]: *cluster-based relative utility* (CBRU) and *cross-sentence informational subsumption* (CSIS). CBRU decides how relevant a particular sentence is to the general topic of the entire cluster and CSIS measure redundancy among sentences. In order to approximate two metrics, three features (i.e. central value, positional value and first-sentence overlap) are used. Next, the final score of each sentence is computed and the selection of sentences is determined. For another related work, see [26].

C. Latent Semantic Analysis

Latent semantic analysis (LSA) which is introduced by [27], is an unsupervised method for extracting a representation of text semantics based on observed words. Gong and Liu [28] initially proposed a method using LSA to select highly ranked sentences for single and multi-document summarization in the news domain. The LSA method first builds a term-sentence matrix (n by m matrix), where each row corresponds to a word from the input (n words) and each column corresponds to a sentence (m sentences). Each entry a_{ij} of the matrix is the weight of the word i in sentence j. The weights of the words are computed by TFIDF technique and if a sentence does not have a word the weight of that word in the sentence is zero. Then singular value decomposition (SVD) is used on the matrix and transforms the matrix A into three matrices: $A = U\Sigma V^T$.

Matrix U ($n \times m$) represents a term-topic matrix having weights of words. Matrix Σ is a diagonal matrix ($m \times m$) where each row i corresponds to the weight of a topic i. Matrix V^T is the topic-sentence matrix. The matrix $D = \Sigma V^T$ describes how much a sentence represent a topic, thus, d_{ij} shows the weight of the topic i in sentence j.

Gong and Liu's method was to choose one sentence per each topic, therefore, based on the length of summary in terms of sentences, they retained the number of topics. This strategy has a drawback due to the fact that a topic may need more than one sentence to convey its information. Consequently, alternative solutions were proposed to improve the performance of LSA-based techniques for summarization. One enhancement was to leverage the weight of each topic to decide the relative size of the summary that should cover the topic, which gives the flexibility of having a variable number of sentences. Another advancement is described in [29]. Steinberger et al. [29] introduced a LSA-based method which achieves a significantly better performance than the original work. They realized that the sentences that discuss some of important topics are good candidates for summaries, thus, in order to locate those sentences they defined the weight of the sentence as follows:

Let g be the "weight" function, then

$$g(s_i) = \sqrt{\sum_{j=1}^{m} d_{ij}^2} \tag{6}$$

For other variations of LSA technique, see [30], [31].

D. Bayesian Topic Models

Many of the existing multi-document summarization methods have two limitations [32]: *1*) They consider the sentences as independent of each other, so topics embedded in the documents are disregarded. *2*) Sentence scores computed by most existing approaches typically do not have very clear probabilistic interpretations, and many of the sentence scores are calculated using heuristics.

Bayesian topic models are probabilistic models that uncover and represent the topics of documents. They are quite powerful and appealing, because they represent the information (i.e. topics) that are lost in other approaches. Their advantage in describing and representing topics in detail enables the development of summarizer systems which can determine the similarities and differences between documents to be used in summarization [33].

Apart from enhancement of topic and document representation, topic models often utilize a distinct measure for scoring the sentence called Kullbak-Liebler (KL). The KL is a measure of difference (divergence) between two probability distributions P and Q [34]. In summarization where we have probability of words, the KL divergence of Q from P over the words w is defined as:

$$D_{KL}(P||Q) = \sum_{w} P(w) \log \frac{P(w)}{Q(w)} \tag{7}$$

where $P(w)$ and $Q(w)$ are probabilities of w in P and Q.

KL divergence is an interesting method for scoring sentences in the summarization, because it shows the fact that good summaries are intuitively similar to the input documents. It describes how the importance of words alters in the summary in comparison with the input, i.e. the KL divergence of a good summary and the input will be low.

Probabilistic topic models have gained dramatic attention in recent years in various domains [35]–[43]. *Latent Dirichlet allocation* (LDA) model is the state of the art unsupervised technique for extracting thematic information (topics) of a collection of documents. A complete review for LDA can be found in [44], [45], but the main idea is that documents are represented as a random mixture of latent topics, where each topic is a probability distribution over words.

LDA has been extensively used for multi-document summarization recently. For example, Daume et al. [46] proposed BAYESUM, a Bayesian summarization model for query-focused summarization. Wang et al. [32] introduced a Bayesian sentence-based topic model for summarization which used both term-document and term-sentence associations. Their system achieved significance performance and outperformed many other summarization methods. Celikyilmaz et al. [47] describe multi-document summarization as a prediction problem based on a two-phase hybrid model. First, they propose a hierarchical topic model to discover the topic structures of all sentences. Then, they compute the similarities of candidate sentences with human-provided summaries using a novel tree-based sentence scoring function. In the second step they make use of these scores and train a regression model according the lexical and structural characteristics of the sentences, and employ the model to score sentences of new documents (unseen documents) to form a summary.

IV. KNOWLEDGE BASES AND AUTOMATIC SUMMARIZATION

The goal of automatic text summarization is to create summaries that are similar to human-created summaries. However, in many cases, the soundness and readability of created summaries are not satisfactory, because the summaries do not cover all the semantically relevant aspects of data in an effective way. This is because many of the existing text summarization techniques do not consider the semantics of words. A step towards building more accurate summarization systems is to combine summarization techniques with knowledge bases (semantic-based or ontology-based summarizers).

The advent of human-generated knowledge bases and various ontologies in many different domains (e.g. Wikipedia, YAGO, DBpedia, etc.) has opened further possibilities in text summarization , and reached increasing attention recently. For example, Henning et al. [48] present an approach to sentence extraction that maps sentences to concepts of an ontology. By considering the ontology features, they can improve the semantic representation of sentences which is beneficial in selection of sentences for summaries. They experimentally showed that ontology-based extraction of sentences outperforms baseline summarizers. Chen et al. [49] introduce a user query-based text summarizer that uses the UMLS medical ontology to make a summary for medical text. Baralis et al. [50] propose a Yago-based summarizer that leverages YAGO ontology [51] to identify key concepts in the documents. The concepts are evaluated and then used to select the most representative document sentences. Sankarasubramaniam et al. [52] introduce an approach that employs Wikipedia in conjunction with a graph-based ranking technique. First, they create a bipartite sentence-concept graph, and then use an iterative ranking algorithm for selecting summary sentences.

V. IMPACT OF CONTEXT IN SUMMARIZATION

Summarization systems often have additional evidence they can utilize in order to specify the most important topics of document(s). For example when summarizing blogs, there are discussions or comments coming after the blog post that are good sources of information to determine which parts of the blog are critical and interesting. In scientific paper summarization, there is a considerable amount of information such as cited papers and conference information which can be leveraged to identify important sentences in the original paper. In the following, we describe some the contexts in more details.

A. Web Summarization

Web pages contains lots of elements which cannot be summarized such as pictures. The textual information they have is often scarce, which makes applying text summarization techniques limited. Nonetheless, we can consider the context of a web page, i.e. pieces of information extracted from content of all the pages linking to it, as additional material to improve summarization. The earliest research in this regard is [53] where they query web search engines and fetch the pages having links to the specified web page. Then they analyze the candidate pages and select the best sentences containing links to the web page heuristically. Delort et al. [54] extended and improved this approach by using an algorithm trying to select a sentence about the same topic that covers as many aspects of the web page as possible.

For blog summarization, [55] proposed a method that first derives representative words from comments and then selects important sentences from the blog post containing representative words. For more related works, see [56]–[58].

B. Scientific Articles Summarization

A useful source of information when summarizing a scientific paper (i.e. citation-based summarization) is to find other papers that cite the target paper and extract the sentences in which the references take place in order to identify the important aspects of the target paper. Mei et al. [59] propose a language model that gives a probability to each word in the citation context sentences. They then score the importance of sentences in the original paper using the KL divergence method (i.e. finding the similarity between a sentence and the language model). For more information, see [60], [61].

C. Email Summarization

Email has some distinct characteristics that indicates the aspects of both spoken conversation and written text. For example, summarization techniques must consider the interactive nature of the dialog as in spoken conversations. Nenkova et al. [62] presented early research in this regard, by proposing a method to generate a summary for the first two levels of the thread discussion. A thread consists of one or more conversations between two or more participants over time. They select a message from the root message and from each response to the root, considering the overlap with root context. Rambow et al. [63] used a machine learning technique and included features related to the thread as well as features of the email structure such as position of the sentence in the tread, number of recipients, etc. Newman et al. [64] describe a system to summarize a full mailbox rather than a single thread by clustering messages into topical groups and then extracting summaries for each cluster.

VI. Indicator Representation Approaches

Indicator representation approaches aim to model the representation of the text based on a set of features and use them to directly rank the sentences rather than representing the topics of the input text. Graph-based methods and machine learning techniques are often employed to determine the important sentences to be included in the summary.

A. Graph Methods for Summarization

Graph methods, which are influenced by PageRank algorithm [65], represent the documents as a connected graph. Sentences form the vertices of the graph and edges between the sentences indicate how similar the two sentences are. A common technique employed to connect two vertices is to measure the similarity of two sentences and if it is greater then a threshold they are connected. The most often used method for similarity measure is cosine similarity with TFIDF weights for words.

This graph representation results in two outcomes. First, the partitions (sub-graphs) included in the graph, create discrete topics covered in the documents. The second outcome is the identification of the important sentences in the document. Sentences that are connected to many other sentences in the partition are possibly the center of the graph and more likely to be included in the summary.

Graph-based methods can be used for single as well as multi-document summarization [10]. Since they do not need language-specific linguistic processing other than sentence and word boundary detection, they can also be applied to various languages [66]. Nonetheless, using TFIDF weighting scheme for similarity measure has limitations, because it only preserves frequency of words and does not take the syntactic and semantic information into account. Thus, similarity measures based on syntactic and semantic information enhances the performance of the summarization system [67]. For more graph-based approaches, see [15].

B. Machine Learning for Summarization

Machine learning approaches model the summarization as a classification problem. [68] is an early research attempt at applying machine learning techniques for summarization. Kupiec et al. develop a classification function, *naive-Bayes classifier*, to classify the sentences as summary sentences and non-summary sentences based on the features they have, given a training set of documents and their extractive summaries. The classification probabilities are learned statistically from the training data using Bayes' rule:

$$P(s \in \mathcal{S}|F_1, F_2, \ldots, F_k) = \frac{P(F_1, F_2, \ldots, F_k)|s \in \mathcal{S})P(s \in \mathcal{S})}{P(F_1, F_2, \ldots, F_k)} \tag{8}$$

Where, s is a sentence from the document collection, $F_1, F_2, \ldots, F_k$ are features used in classification and $\mathcal{S}$ is the summary to be generated. Assuming the conditional independence between the features:

$$P(s \in \mathcal{S}|F_1, F_2, \ldots, F_k) = \frac{\prod_{i=1}^{k} P(F_i|s \in \mathcal{S})P(s \in \mathcal{S})}{\prod_{i=1}^{k} P(F_i).} \tag{9}$$

The probability a sentence to belongs to the summary is the score of the sentence. The selected classifier plays the role of a sentence scoring function. Some of the frequent features used in summarization include the position of sentences in the document, sentence length, presence of uppercase words, similarity of the sentence to the document title, etc. Machine learning approaches have been widely used in summarization by [69]–[71], to name a few.

Naive Bayes, decision trees, support vector machines, Hidden Markov models and Conditional Random Fields are among the most common machine learning techniques used for summarization. One fundamental difference between classifiers is that sentences to be included in the summary have to be decided *independently*. It turns out that methods explicitly assuming the dependency between sentences such as Hidden Markov model [72] and Conditional Random Fields [73] often outperform other techniques.

One of the primary issues in utilizing supervised learning methods for summarization is that they need a set of training documents (labeled data) to train the classifier, which may not be always easily available. Researchers have proposed some alternatives to cope with this issue:

- **Annotated corpora creation:** Creating annotated corpus for summarization greatly benefits the researchers, because more public benchmarks will be available which makes it easier to compare different summarization approaches together. It also lowers the risk of overfitting with a limited data. Ulrich et al. [74] introduce a publicly available annotated email corpus and its creation process. However, creating annotated corpus is very time consuming and more critically, there is no standard agreement on choosing the sentences, and different people may select varied sentences to construct the summary.
- **Semi-supervised approaches:** Using a semi-supervised technique to train a classifier. In semi-supervised learning we utilize the unlabeled data in training. There is usually a small amount of labeled data along with a large amount of unlabeled data. For complete overview of semi-supervised learning, see [75]. Wong et al. [70] proposed a semi-supervised method for extractive summarization. They co-trained two classifiers iteratively to exploit unlabeled data. In each iteration, the unlabeled training examples (sentences) with top scores are included in the labeled training set, and the two classifiers are trained on the new training data.

Machine learning methods have been shown to be very effective and successful in single and multi-document summarization, specifically in class specific summarization where classifiers are trained to locate particular type of information such as scientific paper summarization [61], [76], [77] and biographical summaries [78]–[80].

VII. Evaluation

Evaluation of a summary is a difficult task because there is no ideal summary for a document or a collection of documents and the definition of a good summary is an open question to large extent [16]. It has been found that human summarizers have low agreement for evaluating and producing summaries. Additionally, prevalent use of various metrics and the lack of a standard evaluation metric has also caused summary evaluation to be difficult and challenging.

A. Evaluation of Automatically Produced Summaries

There have been several evaluation campaigns since the late 1990s in the US [16]. They include SUMMAC (1996-1998) [81], DUC (the Document Understanding Conference, 2000-2007) [82], and more recently TAC (the Text Analysis Conference, 2008-present) [1]. These conferences have primary role in design of evaluation standards and evaluate the summaries based on human as well as automatic scoring of the summaries.

In order to be able to do automatic summary evaluation, we need to conquer three major difficulties: *i*) It is fundamental to decide and specify the most important parts of the original text to preserve. *ii*) Evaluators have to automatically identify these pieces of important information in the candidate summary, since this information can be represented using disparate expressions. *iii*) The readability of the summary in terms of grammar and coherence has to be evaluated.

B. Human Evaluation

The simplest way to evaluate a summary is to have a human assess its quality. For example, in DUC, the judges would evaluate the coverage of the summary, i.e. how much the candidate summary covered the original given input. In more recent paradigms, in particular TAC, query-based summaries have been created. Then judges evaluate to what extent a summary answers the given query. The factors that human experts must consider when giving scores to each candidate summary are grammar, non redundancy, integration of most important pieces of information, structure and coherence. For more information, see [16].

C. Automatic Evaluation Methods

There has been a set of metrics to automatically evaluate summaries since the early 2000s. ROUGE is the most widely used metric for automatic evaluation.

1) ROUGE: Lin [83] introduced a set of metrics called Recall-Oriented Understudy for Gisting Evaluation (ROUGE) to automatically determine the quality of a summary by comparing it to human (reference) summaries. There are several variations of ROUGE (see [83]), and here we just mention the most broadly used ones:

- **ROUGE-n:** This metric is recall-based measure and based on comparison of n-grams. a series of n-grams (mostly two and three and rarely four) is elicited from the reference summaries and the candidate summary (automatically generated summary). Let p be "the number of common n-grams between candidate and reference summary", and q be "the number of n-grams extracted from the reference summary only". The score is computed as:
$$\text{ROUGE-}n = \frac{p}{q} \tag{10}$$
- **ROUGE-L:** This measure employs the concept of *longest common subsequence* (LCS) between the two sequences of text. The intuition is that the longer the LCS between two summary sentences, the more similar they are. Although this metric is more flexible than the previous one, it has a drawback that all n-grams must be consecutive. For more information about this metric and its refined metric, see [83].
- **ROUGE-SU:** This metric called *skip bi-gram and unigram* ROUGE and considers bi-grams as well as unigrams. This metric allows insertion of words between the first and the last words of the bi-grams, so they do not need to be consecutive sequences of words.

[1] `http://www.nist.gov/tac/about/index.html`

VIII. Conclusions

The increasing growth of the Internet has made a huge amount of information available. It is difficult for humans to summarize large amounts of text. Thus, there is an immense need for automatic summarization tools in this age of information overload. In this paper, we emphasized various extractive approaches for single and multi-document summarization. We described some of the most extensively used methods such as topic representation approaches, frequency-driven methods, graph-based and machine learning techniques. Although it is not feasible to explain all diverse algorithms and approaches comprehensively in this paper, we think it provides a good insight into recent trends and progresses in automatic summarization methods and describes the state-of-the-art in this research area.

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Aggregation Operator for Assignment of Resources in Distributed Systems

David L. la Red Martínez
Northeastern National University,
Corrientes, Argentine

***Abstract*—In distributed processing systems it is often necessary to coordinate the allocation of shared resources that should be assigned to processes in the modality of mutual exclusion; in such cases, the order in which the shared resources will be assigned to processes that require them must be decided; in this paper we propose an aggregation operator (which could be used by a shared resources manager module) that will decide the order of allocation of the resources to the processes considering the requirements of the processes (shared resources) and the state of the distributed nodes where the processes operate (their computational load).**

***Keywords*—Aggregation operators; concurrency control; communication between groups of processes; mutual exclusion; operating systems; processor scheduling**

I. Introduction

The proliferation of computer systems, many of them distributed in different nodes with multiple processes that cooperate for the achievement of a particular function, require decision models that allow groups of processes to use shared resources that can only be accessed in the modality of mutual exclusion.

The traditional solutions for this problem are found in [1] and [2], which describe the main synchronization algorithms in distributed systems; in [3], it presents an efficient and fault tolerant solution for the problem of distributed mutual exclusion; in [4]-[6], which present algorithms to manage the mutual exclusion in computer networks; in [7], which details the main algorithms for distributed process management, distributed global states and distributed mutual exclusion.

In addition, a reliable communication protocol in the presence of faults is presented in [8]. In [9] a multicast communication protocol is presented for groups of processes in the atomic mode, [10] study technologies, web services and applications of reliable distributed systems; in [11] reliable communication protocols are presented in broadcast mode; in [12] the main communication algorithms in distributed systems are described, [13] describes a network architecture for large-scale virtual environments to support communication between groups of distributed processes, and in [14] the main algorithms of distributed coordination and management of the mutual exclusion.

Similarly, in [15] the communication between groups of processes is analyzed in depth, analyzing protocols such as FLIP: Fast Local Internet Protocol and BP: Broadcast Protocol, analyzing reliable and efficient group communication, parallel programming, the fault-tolerant programming using broadcasting and proposing a three-level architecture, the lower one for FLIP protocol, the medium for communication in groups of processes and the upper one for the applications. Additional information can be found in [16].

Also, solutions (which may be considered classic or traditional) have been proposed for very different types of systems distributed in [17]-[21]. Other works focused on ensuring mutual exclusion have been presented in [22] and [23]. An interesting distributed solution based on permissions is presented in [24] and a solution based on process priorities in [25].

The traditional solutions for the allocation of shared resources distributed in the modality of mutual exclusion are concentrated on guaranteeing mutual exclusion, without considering the computational load on the nodes where the processes operate and the impact that will create on the access to the shared resources requested by the processes in the context of such load.

However, this allocation of resources in processes should be performed taking into account the priorities of the processes and also the current workload of the computational nodes on which the processes are executed.

The new decision models for allocating shared resources could be executed in the context of a shared resource manager for the distributed system, which would receive the shared resource requirements of the processes running on the different distributed nodes, as well as the computational load state of the nodes and, considering that information, the order (priority) of allocation of the requested resources for the requesting processes should be decided on. Consequently, there is a need for specially designed aggregation operators.

In this paper, a new aggregation operator will be presented specifically for the aforementioned problem. This falls under the category of OWA (Ordered Weighted Averaging) operators, and more specifically Neat OWA.

The use of aggregation operators in group decision models has been extensively studied, for example, in [26] a group decision model is presented with the use of aggregation operators of the OWA family; in [27] the use of OWA aggregation operators (Ordered Weighted Averaging) for decision making is presented; in [28] methodologies are introduced to solve problems in the presence of multiple attributes and criteria and in [29] the way of obtaining a collective priority vector is studied, which is created from different formats of expression of the preferences of the decision makers. The model can reduce the complexity of decision making and avoid the loss of information when the different formats are transformed into a unique format of expression of the preferences.

Also, in [30]-[32] several aggregation operators that can be used to make decisions in groups are presented; in [33] the operator WKC-OWA is presented to add information on problems of democratic decision; in [34] a group decision model is presented with the use of linguistic tags and a new form for expression of the preferences of the decision makers; in [35] the main mathematical properties and behavioral measures related to aggregation operators are presented; in [36] a review about aggregation operators, especially those of the OWA family is presented; in [37]-[39] majority aggregation operators and their possible applications to group decision making are analyzed; in [40] and [41] the OWA (Ordered Weighted Averaging) operators applied to multicriteria decision making are presented and analyzed, and in [42] and [43] the OWA operators and their applications in the Multi-agent decision making are discussed.

In turn, in [44] the connection of the linguistic hierarchy and the numerical scale for the 2-tuple linguistic model and its use to treat unbalanced linguistic information is studied; in [45] a complex and dynamic problem of group decision making with multiple attributes is defined and a resolution method that uses a consensus process for groups of attributes, alternatives and preferences, resulting in a decision model for real-world problems is proposed.

This article, which will present an innovative method for shared resource management in distributed systems, has been structured as follows: Section 2 will explain the data structures to be used by the proposed operator, in Section 3 the aggregation operator is described, Section 4 will show a detailed example of this, then the Conclusions and Future Work Lines will be presented, ending with the Acknowledgments and References.

II. Data Structures to be Used

The following premises and data structures will be used.

You have groups of processes distributed in process nodes that access critical resources. These resources are shared in the form of distributed mutual exclusion and it must be decided, according to the demand for resources by the processes, what the priorities to allocate the resources to the processes that require them will be (only the available resources that have not yet been allocated to processes will need to be considered):

- The access permission to the shared resources of a node will not only depend on whether the nodes are using them or not, but on the aggregation value of the preferences (priorities) of the different nodes regarding granting access to shared resources (alternatives) as well.
- The opinions (priorities) of the different nodes regarding granting access to shared resources (alternatives) will depend on the consideration of the value of variables that represent the state of each of the different nodes. Each node must express its priorities for assigning the different shared resources according to the resource requirements of each process (which may be part of a group of processes).

Nodes hosting processes: 1, …. , n. The set of nodes is represented as follows:

Nodes = $\{n_1, \ldots, n_n\}$

Processes housed in each of the n nodes: 1, …. , p. The set of processes is represented as follows:

Processes = $\{p_{ij}\}$ with $i = 1, \ldots, n$ (number of nodes in the distributed system) and $j = 1, \ldots, p$ (maximum number of processes in each node), which can be expressed by the Table 1.

TABLE I. PROCESSES AT EACH NODE

Nodes	**Processes**			
1	p_{11}	p_{12}	….	p_{1p}
….	….	….	…	….
i	p_{i1}	p_{i2}	….	p_{ip}
….	….	….	…	….
n	p_{n1}	p_{n2}	….	p_{np}

Distributed process *Groups*: 1, …. , g. The set of distributed process groups is represented as follows:

Groups = $\{p_{ij}\}$ with i indicating the node and j the process in this node.

Size of each of the g process groups. The number of processes in each group indicates the group's cardinality and is represented as follows:

Card = $\{card(g_i)\}$ with $i = 1, \ldots, g$ indicating the group.

Group priority of each of the g processes groups. These priorities can be set according to different criteria; in this proposal, it will be considered to be a function of the cardinality of each group and is represented as follows:

$prg = \{prg_i = card(g_i)\}$ with $i = 1, \ldots, g$ indicating the group.

Shared *resources* in distributed mutual exclusion mode available on n nodes: 1, …., r. The set of resources is represented as follows:

Resources = $\{r_{ij}\}$ with $i = 1, \ldots, n$ (number of nodes in the distributed system) and $j = 1, \ldots, r$ (maximum number of resources at each node), which can be expressed by Table 2.

TABLE II. SHARED RESOURCES AVAILABLE AT EACH NODE

Nodes	**Resources**			
1	r_{11}	r_{12}	….	r_{1r}
….	….	….	…	….
i	r_{i1}	r_{i2}	….	r_{ir}
….	….	….	…	….
n	r_{n1}	r_{n2}	….	r_{nr}

These available shared resources hosted on different nodes of the distributed system may be required by the processes (clustered or independent) running on the nodes; these requests for resources by the processes are shown in Table 3.

TABLE III. RESOURCES REQUESTED BY PROCESSES

Resources	Processes				
r_{11}	p_{11}	….	p_{kl}	….	p_{np}
….	….	….	…	….	….
r_{ij}	p_{11}	….	p_{kl}	….	p_{np}
….	….	….	…	….	….
r_{nr}	p_{11}	….	p_{kl}	….	p_{np}

Possible *states* of each *process*:

- Independent process.
- Process belonging to a group of processes.

Possible *state* of each of the *nodes*:

- Number of processes.
- Priorities of the processes.
- CPU usage.
- Main memory usage.
- Use of virtual memory.
- Additional memory required for each resource requested by each process (depending on the availability of the data).
- Additional estimated processor load required for each resource requested by each process (depending on data availability).
- Additional estimated input / output load required for each resource requested by each process (depending on data availability).
- Status of each of the shares in the distributed mutual exclusion mode in the node:
  - Assigned to a local or remote process.
  - Available.
- Predisposition (nodal priority) to grant access to each of the *r* shared resources in the modal of distributed mutual exclusion (will result from the consideration of the variables representative of the node status, the priority of the processes and the additional computational load which would mean allocating the resource to the requesting process).
- Current load of the node, which can be calculated as the average of the CPU, memory and input / output usage percentages at any given time (these load indicators may vary depending on the case, some may be added or changed); the current load categories, for example, High, Medium and Low, should also be defined, with value ranges for each category being indicated.

III. DESCRIPTION OF THE AGGREGATION OPERATOR

The proposed operator consists of the following steps:

- Calculation of the current computational load of the nodes.
- Establishment of the categories of computational load and the vectors of weights associated with them.
- Calculation of the priorities or preferences of the processes considering the state of the node (they are calculated in each node for each process).
- Calculation of the priorities or preferences of the processes to access the shared resources available (calculated in the centralized manager of shared resources) and determination of the order and to which process the resources will be allocated.
- Each of the steps above is described below.

A. Calculation of the Current Computational Load of the Nodes

To obtain an indicator of the current computational load of each node, different criteria can be adopted; in this proposal, the criteria will be the percentage of CPU usage, the percentage of memory usage and the percentage of use of input / output operations, as will be seen in the example.

The computational load of each node will be calculated as follows:

Establishment of the number of criteria to determine the load of the nodes:

Card({criteria}) = c

Establishment of the criteria that apply (may differ from one node to another):

Criteria = $\{c_{ij}\}$ with $i = 1, \ldots, n$ (number of nodes in the distributed system) y $j = 1, \ldots, c$ (maximum number of criteria for each node), which can be expressed by the Table 4.

TABLE IV. CRITERIA FOR MEASURING THE COMPUTATIONAL LOAD AT EACH NODE

Nodes	Criteria			
1	c_{11}	c_{12}	….	c_{1c}
….	….	….	…	….
i	c_{i1}	c_{i2}	….	c_{ic}
….	….	….	…	….
n	c_{n1}	c_{n2}	….	c_{nc}

Eventually, all nodes could use the same set of criteria.

Calculation of the computational load of each node:

$Load_i = (\text{value}(c_{i1}) + \ldots + \text{value}(c_{ic})) / c$ *with* $i = 1, \ldots, n$

B. Establishment of the categories of computational load and of the vectors of weights associated thereto

Different criteria can be adopted to establish the current computational load categories of each node; in this proposal, the categories will be: High (if the load is more than 70%), Medium (if the load is between 40% and 70% inclusive) and Low (if the load is less than 40%), as you will see in the example.

Establishment of the number of categories to determine the load of the nodes:

Card({categories}) = a

Establishment of the categories that apply (they may differ from one node to another):

Categories = {cat_{ij}} with i = 1, …, n (number of nodes in the distributed system) and j = 1, …, a (maximum number of categories for each node), which can be expressed by the Table 5.

TABLE V. CATEGORIES TO MEASURE THE COMPUTATIONAL LOAD AT EACH NODE

Nodes	**Categories**			
1	cat_{11}	cat_{12}	….	cat_{1a}
….	….	….	…	….
i	cat_{i1}	cat_{i2}	….	cat_{ia}
….	….	….	…	….
n	cat_{n1}	cat_{n2}	….	cat_{na}

Eventually all nodes could use the same set of categories.

In order to establish the vectors of weights associated with the current computational load categories of each node, different criteria can be adopted; in this proposal, the criteria will be: number of processes in the node, percentage of CPU usage, percentage of memory usage, percentage of virtual memory usage, process priority (process priority in the node where it is executed), memory overhead (additional memory that will require the requested resource to be available, if the data is available), processor overhead (additional processor use that will require the requested resource if the data is available), and input / output overhead (input / additional output that will require to arrange the requested resource, if the data is available), as will be seen in the example.

Establishment of the number of criteria to determine the priority or preference that will be granted in each node according to its load to each order of a shared resource made by each process:

Card({critpref}) = e

Establishment of the criteria that apply (same for all nodes):

Criteria for preferences = {cp_{ij}} with i = 1, …, a (number of categories of computational load) and j = 1, …, e (maximum number of criteria), which can be expressed by Table VI.

TABLE VI. CRITERIA TO CALCULATE THE PRIORITY OR PREFERENCE THAT EACH NODE WILL GRANT TO EACH REQUIREMENT OF EACH PROCESS ACCORDING TO THE LOAD OF THE NODE

Categories	**Criteria**			
1	cp_{11}	cp_{12}	…	cp_{1e}
….	….	….	…	….
i	cp_{i1}	cp_{i2}	…	cp_{ie}
….	….	….	…	….
a	cp_{a1}	cp_{a2}	…	cp_{ae}

Eventually, all nodes could use different sets of criteria applicable to the different categories of computational load; in this proposal and as will be seen in the example, the same criteria are used for all nodes.

First, the categories to indicate the load of the nodes and the criteria that will be applied to evaluate the priority to be given to each request of resources of each process are determined. Then the values corresponding to the criteria that constitute the vectors of weights for the different categories of load are established.

Establishment of vectors of weights (same for all nodes):

Weights = {w_{ij}} con i = 1, …, a (categories number of computational load) y j = 1, …, e (maximum number of criteria), which can be expressed by Table 7.

TABLE VII. WEIGHTS ASSIGNED TO THE CRITERIA TO CALCULATE THE PRIORITY OR PREFERENCE THAT EACH NODE WILL GRANT TO EACH REQUIREMENT OF EACH PROCESS ACCORDING TO THE LOAD OF THE NODE

Categories	**Weights**			
1	w_{11}	w_{12}	….	w_{1e}
….	….	….	…	….
i	w_{i1}	w_{i2}	….	w_{ie}
….	….	….	…	….
a	w_{a1}	w_{a2}	….	w_{ae}

The assignment of weights to the different criteria will be a function of previously performed statistical studies about the distributed system; there will then be a weight assignment function to the criteria for constituting the weight vectors of each load category:

w_{ij} = *norm*(*function*(cp_{ij})) con i = 1, …, a (numbers of category) y j = 1, …, e (numbers of criteria); *norm* indicates that the values must be normalized (in the range of 0 to 1 inclusive) and with the constraints that the sum of the elements of a vector of weights must give 1:

Σ {w_{ij}} = 1 with j = 1, …, e for each constant i.

This means that the sum of the weights assigned to the different criteria will be 1 for each of the categories, or equally, that the sum of elements of the vector of weights of each category is 1.

C. Calculation of the Priorities or Preferences of the Processes taking into Account the Status of the Node (They are calculated in Each Node for Each Process and Could be called Nodal Priorities)

These priorities are calculated at each node for each resource request originated in each process; the calculation considers the corresponding weight vector according to the current load of the node and the vector of the values granted by the node according to the evaluation criteria of the request. The range of values is between 0 and 1, where a value close to 0 means that the related criterion will contribute little to the calculation of the priority of the request, while a value close to 1 means otherwise. Thus a node can influence a request for a resource by a process according to its state and the additional impact or burden that would mean assigning the requested resource to the requesting process, e.g., if accessing the request means increasing the memory usage and the node has little memory available, then it could assign to that criterion a value close to 0, in turn, if the additional processor consumption is considered low and the CPU usage of node is little, then a value close to 1 would be assigned to that criterion.

The valuation vectors that will be applied for each request of a resource by a process, according to the criteria established for the determination of the priority that in each case and moment will fix the node in which the request occurs, are the following:

Valuations (r_{ij} p_{kl}) = {cp_m} con $i = 1, \ldots, n$ (node where the resource resides), $j = 1, \ldots, r$ (resource on node i), $k = 1, \ldots, n$ (node where the process resides), $l = 1, \ldots, p$ (process at node k) and $m = 1, \ldots, e$ (valuation criteria of the requirement priority), which can be expressed by Table 8.

TABLE VIII. EVALUATIONS ASSIGNED TO THE CRITERIA TO CALCULATE THE PRIORITY OR PREFERENCE THAT EACH NODE WILL GRANT EACH REQUIREMENT OF EACH PROCESS ACCORDING TO THE NODE LOAD

Resources - Processes	**Criteria**				
r_{11} p_{11}	cp_1	….	cp_m	….	cp_e
….	….	….	…	….	….
r_{ij} p_{kl}	cp_1	….	cp_m	….	cp_e
….	….	….	…	….	….
r_{nr} p_{np}	cp_1	….	cp_m	….	cp_e

To sum up, the nodal priority (to be calculated at the node where the request occurs) of a process to access a given resource (which can be at any node) is calculated by the scalar product of the mentioned vectors:

Nodal priority (r_{ij} p_{kl}) = Σ w_{om} * cp_m indicating o the weights vector according to the load of the node, keeping the other subscripts, the meanings explained above.

D. Calculation of Process Priorities or Preferences to Access Available Shares (it is calculated in the Centralized Manager of the Shared Resources). In Addition, Determining the Order in Which the Resources will be allocated and to Which Process Each Resource will be allocated

At this stage, the nodal priorities calculated in the previous stage are considered for each requirement of access to resources by the processes. The global or final priorities must be calculated from these nodal priorities, that is, with what priority, or in what order, the requested resources will be provided and to which processes the allocation will be made. The requirements that cannot be attended because they result in low priorities will be considered again in the next iteration of the method.

Table 9 is used for the calculation of the final priorities, in which the priorities or nodal preferences calculated in the previous stage are placed; in this table, each row contains the information of the nodal priorities of the different processes to access a given resource.

Next, it is necessary to calculate the vector of final weights that will be used in the process of aggregation to determine the order or priority of access to the resources.

Final weights = {wf_{kl}} con $k = 1, \ldots, n$ (number of nodes) y $l = 1, \ldots, p$ (maximum number of processes per node), which can be expressed by Table 10, where *np* is the number of processes in the system and prg_i is the priority of the process group to which the process belongs (explained in the previous section).

TABLE IX. NODAL PRIORITIES OF THE PROCESSES TO ACCESS EACH RESOURCE

Resource	**Nodal Priorities of Processes**				
r_{11}	p_{11}	….	p_{kl}	….	p_{np}
….	….	….	…	….	….
r_{ij}	p_{11}	….	p_{kl}	….	p_{np}
….	….	….	…	….	….
r_{nr}	p_{11}	….	p_{kl}	….	p_{np}

TABLE X. WEIGHTS ASSIGNED TO THE PROCESSES TO CALCULATE THE PRIORITY OR FINAL PREFERENCE FOR ACCESS TO RESOURCES

Processes	**Final Weights**	
	If you integrate a group of processes	**If it is independent**
p_{11}	$wf_{11}=(prg_i)/np$	$wf_{11}=1/np$
….	….	….
p_{kl}	$wf_{kl}=(prg_i)/np$	$wf_{kl}=1/np$
….		
p_{np}	$wf_{np}=(prg_i)/np$	$wf_{np}=1/np$

The next step is to normalize the newly obtained weights by dividing each by the sum of all of them, which is indicated in Table 11.

TABLE XI. FINAL NORMALIZED WEIGHTS ASSIGNED TO PROCESSES TO CALCULATE PRIORITY OR FINAL PREFERENCE FOR ACCESS TO RESOURCES

Processes	**Final Normalized Weights**
p_{11}	$nwf_{11} = wf_{11} / \Sigma\, wf_{kl}$
….	….
p_{kl}	$nwf_{kl} = wf_{kl} / \Sigma\, wf_{kl}$
….	….
p_{np}	$nwf_{np} = wf_{np} / \Sigma\, wf_{kl}$

Thus, a normalized weight vector (in the range of 0 to 1 inclusive) is obtained and with the restriction that the sum of the elements of the vector must give 1:

Σ {nwf_{kl}} = 1 with $k = 1, \ldots, n$ (number of nodes) and $l = 1, \ldots, p$ (maximum number of processes per node).

The nodal priorities given in Table 9 taken row by row for each resource will be scalar multiplied by the normalized final weight vector indicated in Table 11. In this way, it is possible to obtain the final global access priorities of each process to each resource. It is indicated below how the order or priority with which the resources will be allocated is obtained and to which process each one will be assigned.

Overall final priority (r_{ij} p_{kl}) = nwf_{kl} * p_{kl} with r_{ij} indicating the resource j of node i, p_{kl} the process l of node k and the product of the overall final priority of the process to access such resource. The greater of these products made for the different processes in relation to the same resource will indicate which of the processes will have access to the resource.

The addition of all these products in relation to the same resource will indicate the priority that will have that resource to be assigned, in relation to the other resources that will also have to be assigned. This is what will be called Distributed Systems Assignment Function (DSAF):

DSAF (r_{ij}) = Σ nwf_{kl} * p_{kl} = resource allocation priority r_{ij}.

By calculating the DSAF for all resources a vector will be obtained, and by ordering its elements from highest to lowest, the priority order of allocation of resources will be obtained. In addition, as already indicated, the largest of the products $nwf_{kl} * p_{kl}$ for each resource will indicate the process to which the resource will be assigned. This is shown in Table 12.

TABLE XII. ORDER OR FINAL PRIORITY OF ALLOCATION OF THE RESOURCES AND PROCESS TO WHICH EACH RESOURCE IS ASSIGNED

Order of allocation of resources	Process to which the resource will be assigned
1°: r_{ij} of the Maximum(DSAF(r_{ij}))	p_{kl} of the Maximum ($nwf_{kl} * p_{kl}$) for r_{ij} assigned
2°: r_{ij} of the Maximum(DSAF(r_{ij})) for unassigned r_{ij}	p_{kl} of the Maximum ($nwf_{kl} * p_{kl}$) for r_{ij} assigned
….	….
Last: unassigned r_{ij}	p_{kl} of the Maximum ($nwf_{kl} * p_{kl}$) for r_{ij} assigned

Considerations for Aggregation Operations

The characteristics of the aggregation operations described allow considering that the proposed method belongs to the family of aggregation operators Neat-OWA, which are characterized by the following:

The definition of OWA operators indicates that $f\left(a_1, a_2, \ldots, a_n\right) = \sum_{j=1}^{n} w_j \cdot b_j$, where b_j is the *jth* highest value of the a_n, with the restriction for weights to satisfy (1) $w_i \in [0,1]$ and (2) $\sum_{i=1}^{n} w_i = 1$.

For the Neat OWA operator family the weights will be calculated according to the elements that are added, or more exactly of the values to be added orderly, the b_j, maintaining conditions (1) and (2). In this case the weights are: $w_i = f_i(b_1,...,b_n)$, defining the operator

$$F(a_1,...a_n) = \sum_i f_i(b_1,...,b_n) \cdot b_i$$

For this family, where the weights depend on the aggregation, the satisfaction of all properties of OWA operators is not required.

In addition, in order to be able to assert that an aggregation operator is *neat*, the final aggregation value needs to be independent of the order of the values. $A = (a_1,...,a_n)$ being the entries to add, $B = (b_1,...,b_n)$ being the ordered entries and $C = (c_1,...,c_n) = Perm(a_1,...,a_n)$ a permutation of the entries. An OWA operator is defined as *neat* if

$$F\left(a_1, a_2, \ldots, a_n\right) = \sum_{i=1}^{n} w_i \cdot b_i$$

It produces the same result for any assignment $C = B$.

One of the characteristics to be pointed out by Neat OWA operators is that the values to be added need not be sorted out for their process. This implies that the formulation of a *neat* operator can be defined by directly using the arguments instead of the orderly elements.

In the proposed aggregation operator, the weights are calculated according to context values. From this context arise the values to be aggregated.

IV. EXAMPLE AND DISCUSSION OF RESULTS

This section will explain in detail an example application of the proposed aggregation operator. The distributed processing system has three nodes:

Nodes = {1, 2, 3}

The processes running on the nodes are as follows: three processes on node 1, five processes on node 2 and seven processes on node 3.

Processes = $\{p_{ij}\}$ with *i* indicating the node and *j* indicating the process, which can be expressed by Table 13.

TABLE XIII. PROCESSES IN EACH NODE

Nodes	Processes						
1	p_{11}	p_{12}	p_{13}				
2	P_{21}	P_{22}	P_{23}	P_{24}	P_{25}		
3	P_{31}	P_{32}	P_{33}	P_{34}	P_{35}	P_{36}	P_{37}

Several processes are independent and others constitute groups of cooperative processes. In this example four groups will be considered, as shown in Table 14.

TABLE XIV. PROCESSES IN EACH GROUP

Groups	Processes						
1	p_{11}	p_{25}	p_{37}				
2	p_{12}	p_{21}					
3	p_{22}	p_{31}					
4	p_{13}	p_{23}	p_{34}				

The number of processes in each group indicates the cardinality of the group and is represented as follows:

Card = {*card* (g_i)} = {3, 2, 2, 3} with *i* indicating the group.

The priority of the groups of processes will be considered the cardinality of each group and is represented as follows:

prg = {prg_i = *card*(g_i)} = {3, 2, 2, 3} with *i* indicating the group.

The shared resources available in the nodes are as follows: three resources in node 1, four resources in node 2 and three resources in node 3.

Resources = {p_{ij}} with *i* indicating the node and *j* indicating the process, as expressed in Table 15.

TABLE XV. SHARED RESOURCES AVAILABLE AT EACH NODE

Nodes	Resources			
1	r_{11}	r_{12}	r_{13}	
2	r_{21}	r_{22}	r_{23}	r_{24}
3	r_{31}	r_{32}	r_{33}	

The requests for resources by the processes are shown in Table 16.

TABLE XVI. RESOURCES REQUESTED BY THE PROCESSES

Resources	Processes
r_{11}	$p_{11}, p_{12}, p_{13}, p_{24}, p_{32}, p_{33}, p_{36}, p_{37}$
r_{12}	$p_{11}, p_{12}, p_{13}, p_{21}, p_{23}, p_{24}, p_{32}, p_{33}, p_{34}, p_{35}, p_{36}, p_{37}$
r_{13}	$p_{13}, p_{21}, p_{31}, p_{32}, p_{33}, p_{34}, p_{35}, p_{36}$
r_{21}	$p_{11}, p_{12}, p_{13}, p_{22}, p_{25}, p_{33}, p_{36}, p_{37}$
r_{22}	$p_{11}, p_{12}, p_{13}, p_{21}, p_{22}, p_{33}, p_{34}, p_{35}, p_{36}$
r_{23}	$p_{11}, p_{21}, p_{24}, p_{32}, p_{33}, p_{34}$
r_{24}	$p_{11}, p_{23}, p_{24}, p_{34}, p_{35}, p_{36}$
r_{31}	$p_{12}, p_{13}, p_{21}, p_{22}, p_{23}, p_{31}, p_{34}, p_{35}, p_{36}$
r_{32}	$p_{13}, p_{23}, p_{33}, p_{34}, p_{35}, p_{36}, p_{37}$
r_{33}	$p_{12}, p_{13}, p_{21}, p_{22}, p_{23}, p_{31}, p_{33}, p_{34}, p_{35}, p_{36}, p_{37}$

Each of the calculation steps will now be described.

A. *Calculation of the Current Computational Load of the Nodes*

To obtain an indicator of the current computational load of each node, the same three criteria will be adopted in the three nodes:

Card ({criteria}) = 3

Criteria = {% CPU usage, % of memory usage, % use of input / output operations}.

The values to be assumed for the computational load indicators of the three nodes and the average load calculation for each node are shown in Table 17.

B. *Establishment of the Categories of Computational Load and of the Vectors of Weights Associated Thereto*

In this proposal, the categories will be the same for all nodes: High (if the load is greater than 70%), Medium (if the load is between 40% and 70% inclusive) and Low (if the load is less than 40%).

Card ({categories}) = 3

Categories = {High, Medium, Low}

The values obtained for the load categories based on the averages shown in Table 17 are shown in Table 18.

TABLE XVII. VALUES OF THE CRITERIA FOR MEASURING THE COMPUTATIONAL LOAD AT EACH NODE

Nodes	***Criteria of the Values***			
1	80	90	75	Average: 81.67
2	45	50	65	Average: 53.33
3	10	25	35	Average: 23.33

TABLE XVIII. VALUES OF THE CATEGORIES TO MEASURE THE COMPUTATIONAL LOAD AT EACH NODE

Nodes	Values of the Category
1	High
2	Medium
3	Low

To establish the weight vectors associated with the current computational load categories of each node, the following criteria will be used for all nodes and for all load categories: Number of processes in the node, % CPU usage, % memory usage, % virtual memory usage, process priority (process priority in the node where it is executed), memory overhead (additional memory that will require (additional processor use that will require the requested resource to be available, if the data is available) and input / output overhead (additional input / output that will require the requested resource to be available), if the data is available).

Card ({critpref}) = 8.

Criteria for preferences = {Node of processes in the node, % of CPU usage, % of memory usage, % of virtual memory usage, process priority, memory overhead, processor overload, input / output overhead}

Next, the values corresponding to the criteria must be established, constituting the vectors of weights for the different categories of load, which will be the same for all nodes, which is indicated in Table 19.

The sum of the weights assigned to the different criteria is 1 for each of the categories, i.e. the sum of elements of the vector of weights of each category is 1.

C. *Calculation of the Priorities or Preferences of the Processes taking into Account the Status of the Node (they are calculated in Each Node for Each Process and could be Called Nodal Priorities)*

The valuation vectors are applied for each requirement of a resource made by a process, according to the criteria established for the determination of the priority that in each case and moment fixes the node in which the request occurs; each vector of evaluations of each requirement is scalar multiplied by the vector of weights corresponding to the current load category of the node to obtain the priority according to each criterion and the nodal priority granted to each requirement; this is shown in Table 20.

Next it is necessary to calculate the vector of final weights that will be used in the final process of aggregation to determine the order or priority of access to the resources. This is shown in Table 22.

The nodal priorities indicated in Table 21 taken row by row, that is, for each resource, will be scalar multiplied by the normalized final weight vector indicated in Table 22 to obtain the final global access priorities of each process to each resource, and from there, the order or priority with which the resources will be allocated and to which process each one will be assigned, as indicated in Table 23.

D. Calculation of process priorities or preferences to access available shares (it is calculated in the centralized manager of the shared resources). In addition, determining the order in which the resources will be allocated and to which process each resource will be allocated

From the nodal priorities, the global or final priorities must be calculated, that is, with what priority, in what order, the requested resources will be awarded and to which processes such grant will be made. Table XXI is used to calculate the final priorities.

TABLE XIX. WEIGHTS ASSIGNED TO THE CRITERIA TO CALCULATE THE PRIORITY OR PREFERENCE THAT EACH NODE WILL GRANT TO EACH REQUIREMENT OF EACH PROCESS ACCORDING TO THE LOAD OF THE NODE

Categories	**Weights**							
	N° Proc.	**% CPU**	**% Mem.**	**% VM**	**Priority Proc.**	**Load Mem.**	**Load Proc.**	**Load I/O**
High	0.05	0.05	0.1	0.5	0.1	0.1	0.05	0.05
Medium	0.1	0.2	0.3	0.1	0.2	0.05	0.025	0.025
Low	0.1	0.3	0.2	0.2	0.1	0.025	0.025	0.05

TABLE XX. THE VALUATIONS ASSIGNED TO THE CRITERIA TO CALCULATE THE PRIORITY OR NODAL PREFERENCE THAT EACH NODE WILL GRANT EACH REQUIREMENT OF EACH PROCESS ACCORDING TO THE NODE LOAD

Processes–Resources	**Criteria**								**Nodal Priorities**
	# Proc.	**% CPU**	**% Mem.**	**% VM**	**Priority Proc.**	**Load Mem.**	**Load Proc.**	**Priority I/O**	
$p_{11}r_{11}$	0.7	0.5	0.7	0.9	0.8	0.2	0.3	0.4	
Pri($p_{11}r_{11}$)	0.035	0.025	0.07	0.45	0.08	0.02	0.015	0.02	0.715
$p_{11}r_{12}$	0.8	0.7	0.4	0.5	0.3	0.7	0.2	0.4	
Pri($p_{11}r_{12}$)	0.04	0.035	0.04	0.25	0.03	0.07	0.01	0.02	0.495
$p_{11}r_{21}$	0.3	0.4	0.5	0.2	0.9	0.2	0.5	0.7	
Pri($p_{11}r_{21}$)	0.015	0.02	0.05	0.1	0.09	0.02	0.025	0.035	0.355
$p_{11}r_{22}$	0.5	0.5	0.7	0.4	0.8	0.3	0.5	0.6	
Pri($p_{11}r_{22}$)	0.025	0.025	0.07	0.2	0.08	0.03	0.025	0.03	0.485
$p_{11}r_{23}$	0.5	0.6	0.8	0.8	0.95	0.9	0.7	0.6	
Pri($p_{11}r_{23}$)	0.025	0.03	0.08	0.4	0.095	0.09	0.035	0.03	0.785
$p_{11}r_{24}$	0.3	0.5	0.9	0.2	0.6	0.6	0.7	0.4	
Pri($p_{11}r_{24}$)	0.015	0.025	0.09	0.1	0.06	0.06	0.035	0.02	0.405
$p_{12}r_{11}$	0.4	0.7	0.5	0.9	1	0.9	0.8	0.8	
Pri($p_{12}r_{11}$)	0.02	0.035	0.05	0.45	0.1	0.09	0.04	0.04	0.825
$p_{12}r_{12}$	0.2	0.7	0.3	0.7	0.8	0.3	0.8	0.9	
Pri($p_{12}r_{12}$)	0.01	0.035	0.03	0.35	0.08	0.03	0.04	0.045	0.62
$p_{12}r_{21}$	0.7	0.4	0.3	0.7	0.8	0.9	0.5	0.2	
Pri($p_{12}r_{21}$)	0.035	0.02	0.03	0.35	0.08	0.09	0.025	0.01	0.64
$p_{12}r_{22}$	0.9	0.6	0.7	0.7	0.8	0.2	0.5	0.4	
Pri($p_{12}r_{22}$)	0.045	0.03	0.07	0.35	0.08	0.02	0.025	0.02	0.64
$p_{12}r_{31}$	0.2	0.5	0.7	0.7	0.3	0.2	0.7	0.8	
Pri($p_{12}r_{31}$)	0.01	0.025	0.07	0.35	0.03	0.02	0.035	0.04	0.58
$p_{12}r_{33}$	0.4	0.5	0.7	0.9	0.3	0.4	0.5	0.8	
Pri($p_{12}r_{33}$)	0.02	0.025	0.07	0.45	0.03	0.04	0.025	0.04	0.7
$p_{13}r_{11}$	0.5	0.7	0.7	0.8	0.6	0.5	0.7	0.8	
Pri($p_{13}r_{11}$)	0.025	0.035	0.07	0.4	0.06	0.05	0.035	0.04	0.715
$p_{13}r_{12}$	0.7	0.8	0.7	0.4	0.9	0.2	0.9	0.7	
Pri($p_{13}r_{12}$)	0.035	0.04	0.07	0.2	0.09	0.02	0.045	0.035	0.535
$p_{13}r_{13}$	0.7	0.6	0.7	0.8	0.9	0.4	0.8	0.7	
Pri($p_{13}r_{13}$)	0.035	0.03	0.07	0.4	0.09	0.04	0.04	0.035	0.74
$p_{13}r_{21}$	0.7	0.4	0.9	0.3	0.5	0.7	0.2	0.3	
Pri($p_{13}r_{21}$)	0.035	0.02	0.09	0.15	0.05	0.07	0.01	0.015	0.44
$p_{13}r_{22}$	0.5	0.9	0.8	0.3	0.5	0.4	0.9	0.3	
Pri($p_{13}r_{22}$)	0.025	0.045	0.08	0.15	0.05	0.04	0.045	0.015	0.45
$p_{13}r_{31}$	0.5	0.7	0.3	0.6	0.8	0.9	0.9	0.5	
Pri($p_{13}r_{31}$)	0.025	0.035	0.03	0.3	0.08	0.09	0.045	0.025	0.63
$p_{13}r_{32}$	0.6	0.9	0.3	0.6	0.4	0.8	0.7	0.8	
Pri($p_{13}r_{32}$)	0.03	0.045	0.03	0.3	0.04	0.08	0.035	0.04	0.6
$p_{13}r_{33}$	0.6	0.2	0.4	0.6	0.9	0.8	0.5	0.8	
Pri($p_{13}r_{33}$)	0.03	0.01	0.04	0.3	0.09	0.08	0.025	0.04	0.615
$p_{21}r_{12}$	0.2	0.1	0.3	0.8	0.7	0.7	0.5	0.8	
Pri($p_{21}r_{12}$)	0.02	0.02	0.09	0.08	0.14	0.035	0.0125	0.02	0.4175
$p_{21}r_{13}$	0.2	0.4	0.8	0.9	0.7	0.4	0.5	0.2	
Pri($p_{21}r_{13}$)	0.02	0.08	0.24	0.09	0.14	0.02	0.0125	0.005	0.6075
$p_{21}r_{22}$	0.3	0.5	0.8	0.9	0.5	0.6	0.2	0.4	
Pri($p_{21}r_{22}$)	0.03	0.1	0.24	0.09	0.1	0.03	0.005	0.01	0.605
$p_{21}r_{23}$	0.7	0.5	0.6	0.8	0.5	0.2	0.9	0.4	
Pri($p_{21}r_{23}$)	0.07	0.1	0.18	0.08	0.1	0.01	0.0225	0.01	0.5725
$p_{21}r_{31}$	0.7	0.5	0.8	0.6	0.9	0.4	0.9	0.9	

Pri($p_{21}r_{31}$)	0.07	0.1	0.24	0.06	0.18	0.02	0.0225	0.0225	0.715
$p_{21}r_{33}$	0.7	0.4	0.9	0.8	0.4	0.8	0.6	0.6	
Pri($p_{21}r_{33}$)	0.07	0.08	0.27	0.08	0.08	0.04	0.015	0.015	0.65
$p_{22}r_{21}$	0.5	0.4	0.7	0.8	0.6	0.4	0.6	0.9	
Pri($p_{22}r_{21}$)	0.05	0.08	0.21	0.08	0.12	0.02	0.015	0.0225	0.5975
$p_{22}r_{22}$	0.5	0.9	0.6	0.8	0.9	0.4	0.2	0.1	
Pri($p_{22}r_{22}$)	0.05	0.18	0.18	0.08	0.18	0.02	0.005	0.0025	0.6975
$p_{22}r_{31}$	0.5	0.4	0.5	0.2	0.4	0.8	0.2	0.9	
Pri($p_{22}r_{31}$)	0.05	0.08	0.15	0.02	0.08	0.04	0.005	0.0225	0.4475
$p_{22}r_{33}$	0.8	0.4	0.3	0.2	0.8	0.9	0.5	0.8	
Pri($p_{22}r_{33}$)	0.08	0.08	0.09	0.02	0.16	0.045	0.0125	0.02	0.5075
$p_{23}r_{12}$	0.5	0.6	0.8	0.3	0.5	0.7	0.5	0.5	
Pri($p_{23}r_{12}$)	0.05	0.12	0.24	0.03	0.1	0.035	0.0125	0.0125	0.6
$p_{23}r_{24}$	0.6	0.2	0.1	0.7	0.3	0.8	0.9	0.4	
Pri($p_{23}r_{24}$)	0.06	0.04	0.03	0.07	0.06	0.04	0.0225	0.01	0.3325
$p_{23}r_{31}$	0.3	0.1	0.4	0.8	0.7	0.9	0.4	0.6	
Pri($p_{23}r_{31}$)	0.03	0.02	0.12	0.08	0.14	0.045	0.01	0.015	0.46
$p_{23}r_{32}$	0.4	0.4	0.8	0.2	0.4	0.6	0.6	0.6	
Pri($p_{23}r_{32}$)	0.04	0.08	0.24	0.02	0.08	0.03	0.015	0.015	0.52
$p_{23}r_{33}$	0.3	0.6	0.8	0.2	0.9	0.6	0.4	0.2	
Pri($p_{23}r_{33}$)	0.03	0.12	0.24	0.02	0.18	0.03	0.01	0.005	0.635
$p_{24}r_{11}$	0.4	0.6	0.7	0.9	0.5	0.7	0.9	0.5	
Pri($p_{24}r_{11}$)	0.04	0.12	0.21	0.09	0.1	0.035	0.0225	0.0125	0.63
$p_{24}r_{12}$	0.3	0.6	0.7	0.8	0.9	0.7	0.6	0.9	
Pri($p_{24}r_{12}$)	0.03	0.12	0.21	0.08	0.18	0.035	0.015	0.0225	0.6925
$p_{24}r_{23}$	0.4	0.9	0.4	0.8	0.8	0.7	0.6	0.3	
Pri($p_{24}r_{23}$)	0.04	0.18	0.12	0.08	0.16	0.035	0.015	0.0075	0.6375
$p_{24}r_{24}$	0.5	0.8	0.7	0.9	0.3	0.4	0.8	0.7	
Pri($p_{24}r_{24}$)	0.05	0.16	0.21	0.09	0.06	0.02	0.02	0.0175	0.6275
$p_{25}r_{21}$	0.2	0.8	0.8	0.9	0.4	0.5	0.6	0.8	
Pri($p_{25}r_{21}$)	0.02	0.16	0.24	0.09	0.08	0.025	0.015	0.02	0.65
$p_{31}r_{13}$	0.6	0.9	0.6	0.9	0.7	0.4	0.9	0.8	
Pri($p_{31}r_{13}$)	0.06	0.27	0.12	0.18	0.07	0.01	0.0225	0.04	0.7725
$p_{31}r_{31}$	0.8	0.3	0.9	0.5	0.7	0.3	0.9	0.7	
Pri($p_{31}r_{31}$)	0.08	0.09	0.18	0.1	0.07	0.0075	0.0225	0.035	0.585
$p_{31}r_{33}$	0.4	0.7	0.7	0.5	0.9	0.9	0.7	0.7	
Pri($p_{31}r_{33}$)	0.04	0.21	0.14	0.1	0.09	0.0225	0.0175	0.035	0.655
$p_{32}r_{11}$	0.6	0.9	0.8	0.5	0.9	0.7	0.3	0.7	
Pri($p_{32}r_{11}$)	0.06	0.27	0.16	0.1	0.09	0.0175	0.0075	0.035	0.74
$p_{32}r_{12}$	0.7	0.4	0.6	0.9	0.8	1	0.9	0.7	
Pri($p_{32}r_{12}$)	0.07	0.12	0.12	0.18	0.08	0.025	0.0225	0.035	0.6525
$p_{32}r_{13}$	0.8	0.9	1	0.7	0.9	0.3	0.5	0.9	
Pri($p_{32}r_{13}$)	0.08	0.27	0.2	0.14	0.09	0.0075	0.0125	0.045	0.845
$p_{32}r_{23}$	0.8	0.8	1	0.9	0.6	0.8	0.4	0.9	
Pri($p_{32}r_{23}$)	0.08	0.24	0.2	0.18	0.06	0.02	0.01	0.045	0.835
$p_{33}r_{11}$	0.2	0.7	0.9	0.8	0.6	0.9	1	0.3	
Pri($p_{33}r_{11}$)	0.02	0.21	0.18	0.16	0.06	0.0225	0.025	0.015	0.6925
$p_{33}r_{12}$	0.9	1	0.9	0.7	0.3	0.5	0.7	0.3	
Pri($p_{33}r_{12}$)	0.09	0.3	0.18	0.14	0.03	0.0125	0.0175	0.015	0.785
$p_{33}r_{13}$	0.9	0.5	0.7	0.9	0.3	0.4	0.5	0.8	
Pri($p_{33}r_{13}$)	0.09	0.15	0.14	0.18	0.03	0.01	0.0125	0.04	0.6525
$p_{33}r_{21}$	0.4	0.6	0.7	0.8	0.8	0.4	0.8	0.8	
Pri($p_{33}r_{21}$)	0.04	0.18	0.14	0.16	0.08	0.01	0.02	0.04	0.67
$p_{33}r_{22}$	0.9	0.4	0.7	0.8	0.7	0.4	0.9	0.7	
Pri($p_{33}r_{22}$)	0.09	0.12	0.14	0.16	0.07	0.01	0.0225	0.035	0.6475
$p_{33}r_{23}$	0.4	0.6	0.9	1	0.6	0.4	0.7	0.8	
Pri($p_{33}r_{23}$)	0.04	0.18	0.18	0.2	0.06	0.01	0.0175	0.04	0.7275
$p_{33}r_{32}$	0.6	0.6	0.7	0.8	0.4	0.5	0.8	0.8	
Pri($p_{33}r_{32}$)	0.06	0.18	0.14	0.16	0.04	0.0125	0.02	0.04	0.6525
$p_{33}r_{33}$	0.6	1	0.7	0.4	0.6	0.8	0.8	0.9	
Pri($p_{33}r_{33}$)	0.06	0.3	0.14	0.08	0.06	0.02	0.02	0.045	0.725
$p_{34}r_{12}$	0.8	1	0.3	0.5	0.7	0.3	0.8	0.7	
Pri($p_{34}r_{12}$)	0.08	0.3	0.06	0.1	0.07	0.0075	0.02	0.035	0.6725
$p_{34}r_{13}$	0.2	1	0.8	0.5	0.8	0.6	0.9	0.7	
Pri($p_{34}r_{13}$)	0.02	0.3	0.16	0.1	0.08	0.015	0.0225	0.035	0.7325
$p_{34}r_{22}$	0.9	0.8	0.6	0.8	0.9	0.8	0.5	0.6	
Pri($p_{34}r_{22}$)	0.09	0.24	0.12	0.16	0.09	0.02	0.0125	0.03	0.7625
$p_{34}r_{23}$	0.4	0.6	0.7	0.8	0.9	0.5	0.9	0.6	

Pri($p_{34}r_{23}$)	0.04	0.18	0.14	0.16	0.09	0.0125	0.0225	0.03	0.675
$p_{34}r_{24}$	0.9	0.4	0.7	0.4	0.7	0.5	0.9	0.7	
Pri($p_{34}r_{24}$)	0.09	0.12	0.14	0.08	0.07	0.0125	0.0225	0.035	0.57
$p_{34}r_{31}$	0.5	0.6	0.7	0.9	0.7	0.9	0.6	0.7	
Pri($p_{34}r_{31}$)	0.05	0.18	0.14	0.18	0.07	0.0225	0.015	0.035	0.6925
$p_{34}r_{32}$	0.8	0.6	0.9	0.5	0.6	0.9	0.3	0.9	
Pri($p_{34}r_{32}$)	0.08	0.18	0.18	0.1	0.06	0.0225	0.0075	0.045	0.675
$p_{34}r_{33}$	0.4	0.6	0.8	0.5	0.9	0.9	0.4	0.3	
Pri($p_{34}r_{33}$)	0.04	0.18	0.16	0.1	0.09	0.0225	0.01	0.015	0.6175
$p_{35}r_{12}$	0.2	0.4	0.7	0.4	0.9	0.5	0.7	0.9	
Pri($p_{35}r_{12}$)	0.02	0.12	0.14	0.08	0.09	0.0125	0.0175	0.045	0.525
$p_{35}r_{13}$	0.8	0.9	0.7	0.3	0.9	0.8	0.7	0.4	
Pri($p_{35}r_{13}$)	0.08	0.27	0.14	0.06	0.09	0.02	0.0175	0.02	0.6975
$p_{35}r_{22}$	0.3	0.8	0.9	0.4	0.8	0.6	0.3	0.6	
Pri($p_{35}r_{22}$)	0.03	0.24	0.18	0.08	0.08	0.015	0.0075	0.03	0.6625
$p_{35}r_{24}$	0.5	0.8	0.9	0.4	0.6	0.9	0.4	0.7	
Pri($p_{35}r_{24}$)	0.05	0.24	0.18	0.08	0.06	0.0225	0.01	0.035	0.6775
$p_{35}r_{31}$	0.9	0.8	0.7	0.4	0.8	0.3	0.4	0.8	
Pri($p_{35}r_{31}$)	0.09	0.24	0.14	0.08	0.08	0.0075	0.01	0.04	0.6875
$p_{35}r_{32}$	0.9	0.7	0.8	0.6	0.4	0.9	0.4	0.7	
Pri($p_{35}r_{32}$)	0.09	0.21	0.16	0.12	0.04	0.0225	0.01	0.035	0.6875
$p_{35}r_{33}$	0.5	0.7	0.6	0.9	0.8	0.5	0.9	0.7	
Pri($p_{35}r_{33}$)	0.05	0.21	0.12	0.18	0.08	0.0125	0.0225	0.035	0.71
$p_{36}r_{11}$	0.8	0.9	0.6	0.5	0.8	0.9	0.9	0.6	
Pri($p_{36}r_{11}$)	0.08	0.27	0.12	0.1	0.08	0.0225	0.0225	0.03	0.725
$p_{36}r_{12}$	0.7	0.9	0.4	0.9	0.8	0.9	0.4	0.7	
Pri($p_{36}r_{12}$)	0.07	0.27	0.08	0.18	0.08	0.0225	0.01	0.035	0.7475
$p_{36}r_{13}$	0.9	0.9	0.8	0.7	0.8	0.7	0.9	0.7	
Pri($p_{36}r_{13}$)	0.09	0.27	0.16	0.14	0.08	0.0175	0.0225	0.035	0.815
$p_{36}r_{21}$	0.8	0.9	0.5	0.3	0.7	0.7	0.9	0.9	
Pri($p_{36}r_{21}$)	0.08	0.27	0.1	0.06	0.07	0.0175	0.0225	0.045	0.665
$p_{36}r_{22}$	0.8	0.2	0.1	0.3	0.8	0.7	0.6	0.9	
Pri($p_{36}r_{22}$)	0.08	0.06	0.02	0.06	0.08	0.0175	0.015	0.045	0.3775
$p_{36}r_{24}$	0.4	0.7	0.9	0.3	0.8	0.5	0.8	0.9	
Pri($p_{36}r_{24}$)	0.04	0.21	0.18	0.06	0.08	0.0125	0.02	0.045	0.6475
$p_{36}r_{31}$	0.5	0.9	0.9	0.7	0.8	0.8	0.8	0.7	
Pri($p_{36}r_{31}$)	0.05	0.27	0.18	0.14	0.08	0.02	0.02	0.035	0.795
$p_{36}r_{32}$	0.9	0.8	0.6	0.7	0.8	0.5	0.6	0.7	
Pri($p_{36}r_{32}$)	0.09	0.24	0.12	0.14	0.08	0.0125	0.015	0.035	0.7325
$p_{36}r_{33}$	0.2	0.7	0.4	0.8	0.8	0.9	0.4	0.5	
Pri($p_{36}r_{33}$)	0.02	0.21	0.08	0.16	0.08	0.0225	0.01	0.025	0.6075
$p_{37}r_{11}$	0.9	0.6	0.8	0.6	0.9	0.7	0.9	0.8	
Pri($p_{37}r_{11}$)	0.09	0.18	0.16	0.12	0.09	0.0175	0.0225	0.04	0.72
$p_{37}r_{12}$	0.7	0.9	0.8	0.7	0.5	0.8	0.8	0.6	
Pri($p_{37}r_{12}$)	0.07	0.27	0.16	0.14	0.05	0.02	0.02	0.03	0.76
$p_{37}r_{21}$	0.9	0.7	0.8	0.6	0.6	0.9	0.5	0.4	
Pri($p_{37}r_{21}$)	0.09	0.21	0.16	0.12	0.06	0.0225	0.0125	0.02	0.695
$p_{37}r_{32}$	0.8	0.9	0.5	0.3	0.8	0.7	0.4	0.6	
Pri($p_{37}r_{32}$)	0.08	0.27	0.1	0.06	0.08	0.0175	0.01	0.03	0.6475
$p_{37}r_{33}$	0.8	0.4	0.6	0.8	0.8	0.6	0.9	0.3	
Pri($p_{37}r_{33}$)	0.08	0.12	0.12	0.16	0.08	0.015	0.0225	0.015	0.6125

TABLE XXI. NODAL PRIORITIES OF THE PROCESSES TO ACCESS EACH RESOURCE

Resourse	**Nodal Priorities of Processes**													
	p_{11}	p_{12}	p_{13}	p_{21}	p_{22}	p_{23}	p_{24}	p_{25}	p_{31}	p_{32}	p_{33}	p_{34}	p_{35}	p_{36}	p_{37}
r_{11}	0.715	0.825	0.715	0	0	0	0.63	0	0	0.74	0.6925	0	0	0.725	0.72
r_{12}	0.495	0.62	0.535	0.4175	0	0.6	0.6925	0	0	0.6525	0.785	0.6725	0.525	0.7475	0.76
r_{13}	0	0	0.74	0.6075	0	0	0	0	0.7725	0.845	0.6525	0.7325	0.6975	0.815	0
r_{21}	0.355	0.64	0.44	0	0.5975	0	0	0.65	0	0	0.67	0	0	0.665	0.695
r_{22}	0.485	0.64	0.45	0.605	0.6975	0	0	0	0	0	0.6475	0.7625	0.6625	0.3775	0
r_{23}	0.785	0	0	0.5725	0	0	0.6375	0	0	0.835	0.7275	0.675	0	0	0
r_{24}	0.405	0	0	0	0	0.3325	0.6275	0	0	0	0	0.57	0.6775	0.6475	0
r_{31}	0	0.58	0.63	0.715	0.4475	0.46	0	0	0.585	0	0	0.6925	0.6875	0.795	0
r_{32}	0	0	0.6	0	0	0.52	0	0	0	0	0.6525	0.675	0.6875	0.7325	0.6475
r_{33}	0	0.7	0.615	0.65	0.5075	0.635	0	0	0.655	0	0.725	0.6175	0.71	0.6075	0.6125

TABLE XXII. FINAL WEIGHTS AND NORMALIZED FINAL WEIGHTS ASSIGNED TO PROCESSES TO CALCULATE THE PRIORITY OR FINAL PREFERENCE FOR ACCESS TO RESOURCES

	Processes														
	p_{11}	**p_{12}**	**p_{13}**	**p_{21}**	**p_{22}**	**p_{23}**	**p_{24}**	**p_{25}**	**p_{31}**	**p_{32}**	**p_{33}**	**p_{34}**	**p_{35}**	**p_{36}**	**p_{37}**
Final Weights	0.2	0.133	0.2	0.133	0.133	0.2	0.067	0.2	0.133	0.067	0.067	0.2	0.067	0.067	0.2
Normalized Final Weights	0.097	0.065	0.097	0.065	0.065	0.097	0.032	0.097	0.065	0.032	0.032	0.097	0.032	0.032	0.097

TABLE XXIII. FINAL GLOBAL PRIORITIES OF THE PROCESSES TO ACCESS EACH RESOURCE

Resourse	**Final Global Priorities of the Processes**														
	p_{11}	**p_{12}**	**p_{13}**	**p_{21}**	**p_{22}**	**p_{23}**	**p_{24}**	**p_{25}**	**p_{31}**	**p_{32}**	**p_{33}**	**p_{34}**	**p_{35}**	**p_{36}**	**p_{37}**
r_{11}	0.069	0.053	0.069	0	0	0	0.020	0	0	0.024	0.022	0	0	0.023	**0.070**
r_{12}	0.048	0.04	0.052	0.027	0	0.058	0.022	0	0	0.021	0.025	0.065	0.017	0.024	**0.074**
r_{13}	0	0	**0.072**	0.039	0	0	0	0	0.050	0.027	0.021	0.071	0.023	0.026	0
r_{21}	0.034	0.041	0.043	0	0.039	0	0	0.063	0	0	0.022	0	0	0.021	**0.067**
r_{22}	0.047	0.041	0.044	0.039	0.045	0	0	0	0	0	0.021	**0.074**	0.021	0.012	0
r_{23}	**0.076**	0	0	0.037	0	0	0.021	0	0	0.027	0.023	0.065	0	0	0
r_{24}	0.039	0	0	0	0	0.032	0.020	0	0	0	0	**0.055**	0.022	0.021	0
r_{31}	0	0.037	0.061	0.046	0.029	0.045	0	0	0.038	0	0	**0.067**	0.022	0.026	0
r_{32}	0	0	0.058	0	0	0.050	0	0	0	0	0.021	**0.065**	0.022	0.024	0.063
r_{33}	0	0.045	0.060	0.042	0.033	**0.061**	0	0	0.042	0	0.023	0.060	0.023	0.020	0.060

The greatest of these products made for the different processes in relation to the same resource will indicate which of the processes will have access to the resource (in the case of ties the process identified with the smallest number could be chosen); this is shown in bold in Table 23.

The addition of all these products in relation to the same resource will indicate the priority of such resource to be assigned. This is the Distributed Systems Assignment Function (DSAF), which is shown in Table 24.

The final allocation order of the resources and the target processes are obtained by ordering Table 24, which is shown in Table 25.

The next step is to reiterate the procedure, but removing from the requests for resources the assignments already made; it should also be taken into account that the allocated resources will be available when the processes have released them and can therefore be assigned to other processes. The results of successive iterations are shown in Tables 26 to 36.

TABLE XXIV. FINAL GLOBAL PRIORITIES FOR ALLOCATING RESOURCES

DSAF	**Final Global Priority to Assign Resource**	**Processes**
r_{11}	0.35120968	r_{11} al p_{37}
r_{12}	0.47306452	r_{12} al p_{37}
r_{13}	0.32862903	r_{13} al p_{13}
r_{21}	0.33	r_{21} al p_{37}
r_{22}	0.34403226	r_{22} al p_{34}
r_{23}	0.24919355	r_{23} al p_{11}
r_{24}	0.18951613	r_{24} al p_{34}
r_{31}	0.37048387	r_{31} al p_{34}
r_{32}	0.30322581	r_{32} al p_{34}
r_{33}	0.46798387	r_{33} al p_{23}

TABLE XXV. ORDER OR FINAL PRIORITY OF ALLOCATION OF RESOURCES AND PROCESS TO WHICH EACH RESOURCE IS ASSIGNED

Final Global Priority Order	**Assignment**
0.47306452	r_{12} al p_{37}
0.46798387	r_{33} al p_{23}
0.37048387	r_{31} al p_{34}
0.35120968	r_{11} al p_{37}
0.34403226	r_{22} al p_{34}
0.33	r_{21} al p_{37}
0.32862903	r_{13} al p_{13}
0.30322581	r_{32} al p_{34}
0.24919355	r_{23} al p_{11}
0.18951613	r_{24} al p_{34}

TABLE XXVI. ORDER OR FINAL PRIORITY OF ALLOCATION OF RESOURCES AND PROCESS TO WHICH EACH RESOURCE IS ASSIGNED (SECOND ITERATION)

Final Global Priority Order	**Assignment**
0.40653226	r_{33} al p_{34}
0.39951613	r_{12} al p_{34}
0.30346774	r_{31} al p_{13}
0.28153226	r_{11} al p_{11}
0.27024194	r_{22} al p_{11}
0.26274194	r_{21} al p_{25}
0.25701613	r_{13} al p_{34}
0.23790323	r_{32} al p_{37}
0.17322581	r_{23} al p_{34}
0.13435484	r_{24} al p_{11}

TABLE XXVII. ORDER OR FINAL PRIORITY OF ALLOCATION OF RESOURCES AND PROCESS TO WHICH EACH RESOURCE IS ASSIGNED (THIRD ITERATION)

Final Global Priority Order	Assignment
0.34677419	r_{33} al p_{13}
0.33443548	r_{12} al p_{23}
0.2425	r_{31} al p_{21}
0.22330645	r_{22} al p_{13}
0.21233871	r_{11} al p_{13}
0.19983871	r_{21} al p_{13}
0.18612903	r_{13} al p_{31}
0.17524194	r_{32} al p_{13}
0.10790323	r_{23} al p_{21}
0.09516129	r_{24} al p_{23}

TABLE XXVIII. ORDER OR FINAL PRIORITY OF ALLOCATION OF RESOURCES AND PROCESS TO WHICH EACH RESOURCE IS ASSIGNED (FOURTH ITERATION)

Final Global Priority Order	Assignment
0.28725806	r_{33} al p_{37}
0.27637097	r_{12} al p_{13}
0.19637097	r_{31} al p_{23}
0.17975806	r_{22} al p_{12}
0.15725806	r_{21} al p_{12}
0.14314516	r_{11} al p_{12}
0.13629032	r_{13} al p_{21}
0.11717742	r_{32} al p_{23}
0.07096774	r_{23} al p_{32}
0.06298387	r_{24} al p_{35}

TABLE XXIX. ORDER OR FINAL PRIORITY OF ALLOCATION OF RESOURCES AND PROCESS TO WHICH EACH RESOURCE IS ASSIGNED (FIFTH ITERATION)

Final Global Priority Order	Assignment
0.22798387	r_{33} al p_{12}
0.22459677	r_{12} al p_{11}
0.15185484	r_{31} al p_{31}
0.13846774	r_{22} al p_{21}
0.11596774	r_{21} al p_{22}
0.09709677	r_{13} al p_{32}
0.08991935	r_{11} al p_{32}
0.06685484	r_{32} al p_{36}
0.04403226	r_{23} al p_{33}
0.04112903	r_{24} al p_{36}

TABLE XXX. ORDER OR FINAL PRIORITY OF ALLOCATION OF RESOURCES AND PROCESS TO WHICH EACH RESOURCE IS ASSIGNED (SIXTH ITERATION)

Final Global Priority Order	Assignment
0.18282258	r_{33} al p_{31}
0.17669355	r_{12} al p_{12}
0.1141129	r_{31} al p_{12}
0.09943548	r_{22} al p_{22}
0.07741935	r_{21} al p_{11}
0.06983871	r_{13} al p_{36}
0.06604839	r_{11} al p_{36}
0.04322581	r_{32} al p_{35}
0.02056452	r_{23} al p_{24}
0.02024194	r_{24} al p_{24}

TABLE XXXI. ORDER OR FINAL PRIORITY OF ALLOCATION OF RESOURCES AND PROCESS TO WHICH EACH RESOURCE IS ASSIGNED (SEVENTH ITERATION)

Final Global Priority Order	Assignment
0.14056452	r_{33} al p_{21}
0.13669355	r_{12} al p_{21}
0.07669355	r_{31} al p_{22}
0.05443548	r_{22} al p_{35}
0.04354839	r_{13} al p_{35}
0.04306452	r_{21} al p_{33}
0.04266129	r_{11} al p_{33}
0.02104839	r_{32} al p_{33}

TABLE XXXII. ORDER OR FINAL PRIORITY OF ALLOCATION OF RESOURCES AND PROCESS TO WHICH EACH RESOURCE IS ASSIGNED (EIGHTH ITERATION)

Final Global Priority Order	Assignment
0.10975806	r_{12} al p_{33}
0.09862903	r_{33} al p_{22}
0.04782258	r_{31} al p_{36}
0.03306452	r_{22} al p_{33}
0.02145161	r_{21} al p_{36}
0.02104839	r_{13} al p_{33}
0.02032258	r_{11} al p_{24}

TABLE XXXIII. ORDER OR FINAL PRIORITY OF ALLOCATION OF RESOURCES AND PROCESS TO WHICH EACH RESOURCE IS ASSIGNED (NINTH ITERATION)

Final Global Priority Order	Assignment
0.08443548	r_{12} al p_{36}
0.0658871	r_{33} al p_{33}
0.02217742	r_{31} al p_{35}
0.01217742	r_{22} al p_{36}

TABLE XXXIV. ORDER OR FINAL PRIORITY OF ALLOCATION OF RESOURCES AND PROCESS TO WHICH EACH RESOURCE IS ASSIGNED (TENTH ITERATION)

Final Global Priority Order	Assignment
0.06032258	r_{12} al p_{24}
0.0425	r_{33} al p_{35}

TABLE XXXV. ORDER OR FINAL PRIORITY OF ALLOCATION OF RESOURCES AND PROCESS TO WHICH EACH RESOURCE IS ASSIGNED (ELEVENTH ITERATION)

Final Global Priority Order	Assignment
0.03798387	r_{12} al p_{32}
0.01959677	r_{33} al p_{36}

TABLE XXXVI. ORDER OR FINAL PRIORITY OF ALLOCATION OF RESOURCES AND PROCESS TO WHICH EACH RESOURCE IS ASSIGNED (TWELFTH ITERATION)

Final Global Priority Order	Assignment
0.01693548	r_{12} al p_{35}

In this way, all the requests for resources of all the processes have been taken care of, respecting the mutual exclusion and the priorities of the processes, the nodal priorities and the final priorities.

V. FINAL CONSIDERATIONS

A. Conclusions

The proposed model makes it possible for the distributed system to self-regulate repeatedly according to the local state of the n nodes, resulting in an update of their local states, as a consequence of the evolution of their respective processes and the decisions of access to resources: the distributed system in which groups of processes requiring access to critical resources are executed, produces access decisions to resources that modify the state of the system and readjusts it repetitively, also guaranteeing the mutual exclusion in access to the shared resources, indicating the priority of granting access to each resource and the process to which it is assigned. This process is repeated as long as there are processes that request access to shared resources.

The proposed model includes as a particular case one of the most used methods, consisting in considering only the priority of the processes, instead of a group of state variables of each node. Another notable feature of the proposal is its ease of deployment in a centralized shared resource manager environment of a distributed system.

B. Future Work

It is planned to develop variants of the proposed method considering other aggregation operators (especially the OWA family) and the possibility of being used by a resource manager shared (instead of centralized as in the proposed method).

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Feature Weight Optimization Mechanism for Email Spam Detection based on Two-Step Clustering Algorithm and Logistic Regression Method

Ahmed Hamza Osman
Department of Information System,
Faculty of Computing and Information Technology
King Abdulaziz University
Jeddah, Kingdom of Saudi Arabia

Hani Moaiteq Aljahdali
Department of Information System,
Faculty of Computing and Information Technology
King Abdulaziz University
Jeddah, Kingdom of Saudi Arabia

***Abstract*—This research proposed an improved filtering spam technique for suspected emails, messages based on feature weight and the combination of two-step clustering and logistic regression algorithm. Unique, important features are used as the optimum input for a hybrid proposed approach. This study adopted a spam detector model based on distance measure and threshold value. The aim of this model was to study and select distinct features for email filtering using feature weight method as dimension reduction. Two-step clustering algorithm was used to generate a new feature called "Label" to cluster and differentiate the diversity emails and group them based on the inter samples similarity. Thereby the spam filtering process was simplified using the Logistic regression classifier in order to distinguish the hidden patterns of spam and non-spam emails. Experimental design was conducted based on the UCI spam dataset. The outcome of the findings shows that the results of the email filtering are promising compared to other modern spam filtering methods.**

***Keywords*—Two-step clustering; spam filtering; classification; detection; feature weight; logistic regression**

I. INTRODUCTION

Nowadays, email messages are considered as economic and most essential communicative way in the world. It is efficient, simple and accessible for all due to the internet availability. The availability of email makes it susceptible to many hackers and threats [1]. Spam is considered as a very important threat to email; practically all email users in the world tolerate spam. The term spam was used to define the undesirable message, junk-mails sent to web users' inbox. It is most opportune for email spammers to send lots of messages to millions of users simply and without cost [2]. This makes it a public situation for all web users to receive unsolicited email regularly.

The versatile way of unsolicited email by the utilization of immense mailing tools prompts the requirement for spam recognition. Execution of various spam discovery strategies in view of machine learning methods was proposed to address the issue of various email spam desolating the system. Past calculation utilized as a part of email spam identification contrasts each email message and spam and non-spam information before creating finders. This study' proposed system propelled by the two-step grouping calculation with strategic relapse system utilizes highlights weight as advancement procedure to produce locators to cover the spam space.

Diverse strategies have been embraced to stop the danger of spam or to definitely lessen its measure. An anti-spam law was authorized by enacting a punishment for spammers who circulate email spam [3]. In spite of the diverse methodologies and strategies that have been received to battle the danger of email spam, the web today still shows a huge measure of spam [4]-[6]. Therefore, more consideration is required with respect to how the risk can be radically diminished if not completely disposed. The fight against email spam is an extremely troublesome fight; therefore, it bodes well to battle a versatile email spam generator with a versatile system.

In this study, a new hybrid method that is inspired by descriptive and predictive models will be introduced. It consists of a Logistic Regression Method (LRM) as a prediction method with the integrated effort of Two-step Clustering Algorithm (TSCA) as description technique. To produce more precise filtering results, the standard dimension of spam dataset has been reduced based on feature weight (FW). The engineering aims required in this study's hybrid method can be viewed in three ways; firstly, generating new dataset based on feature weight (FW) to reduce the dataset dimensionality; secondly, to limit the maximizing distance between spam detectors and the non-spam space by using two-step clustering algorithm (TSCA); and thirdly, is to filter the email to spam and no-spam using logistic regression method (LRM) based on the output of FW and TSCA. The aim of this study is to find possible increase in the accuracy and reduction in the miss-filtering emails.

This article is structured into six sections: Section 1 discusses the motivation and Introduction; Section 2 covers the article related work, the improved method, and its integral system will be described in Section 3. Experimental design and results of the study and discussions in details are in Section 4 and Section 5, respectively. The conclusion of the research is described in Section 6.

II. Related Works

Several attempts have been proposed to block spammers and reduce a number of undesirable emails across the internet and user's inbox. One of these attempts is called anti-spam law [3]. This law was defined by enacting a penalty for spam users who send spam emails to user's inbox. Another two common methods have been proposed in email spam detection; a Machine Learning (ML) method, a data mining (DM) and knowledge discovery (KDD) method [4]. In the DM method, researchers introduced an origin-based filter technique based on web protocol address approach to differentiate the spam and non-spam messages. On the other hand, in the KDD method, researchers categorized spam or non-spam message based on sets of generating rules using KDD algorithms as filter techniques. The authors claim a promising spam filtering results. However, they need to update the rules continuously, which is time wasting and inadequate for many users. Spam detection based on ML is not required to generate and update any rules as DM and KDD based methods; only training data for classifying an email message is required. Classification techniques based on email messages characteristics were applied to learn the filtering rules and to distinct spam and non-spam email messages [5].

Some approaches were adopted to stop the spam, however, the web still currently observe a large set of spam [6], [7]. Therefore, more consideration is required by improving spam detection algorithm on how the threat can be significantly decreased if not completely excluded. For this aspect, many spam-filtering algorithms have been applied in machine learning [5]. Examples of these algorithms include neural network (NN), Support Vector Machine (SVM), k-nearest neighbor (KNN), and Naïve Bayes (NB). Several studies in machine learning approach applied in email spam filtering (Table 1). Marsono et al. [8] implemented naïve Bayes email spam filtering based on layer processing, without any requirement for reassembling. They suggested controlling middle boxes step to filter the received email spam from the email servers [9]. W. El-Kharashi et al. proposed a spam controlling method using hardware structure of naïve Bayesian inference engine [10]. The method can categorize more than 117 million features per-second based on probability inputs [10]. Y. Tang et al. introduced a model that applied the SVM for email filtering. This model extracts spammers behavior using the distribution of the global senders and then investigate them by assigning a value of no-spam to each IP-address email sender [11]. Their empirical results presented that the SVM technique is precise and faster than the Random Forests (RF) algorithm [11]. Yoo, S., et al. presented an email classification method called Priority E-mail Personalized technique (PEP) [12]. The PEP focused on analyzing the personal social networks to detect user groups and to achieve the user viewpoint based on the user social roles and then apply them for email message classification. Silva et al. [13], [14] assessed the neural network algorithm for internet spam. They also investigated how different groups of features influence the filtering accuracy rate. Largilliere and Peyronnet [15] developed a combination approach for internet email spamming on the PageRank method. Liu et al. [16] introduced features of user behavior for distinguishing spam and non-spam pages. They also developed a hybrid machine learning system aided by user-behavior to filter spam pages [16]. Content-based features method were proposed by Castilho et al. [17] and Rungsawang et al. [18]. These studies investigated and extracted both link features and content for spam filtering pages with some improving email spam detection using ant colony optimization method [18]. Also, they used the topology of the web-graph by extracting the web link dependencies between the internet pages.

The logistic regression method has some benefits compared to other classification methods such as SVM and Naive Bayes. The excessively robust conditional independence assumptions of Naïve-Bayes and SVM mean that if two variables are correlated, the naïve-Bayes and SVM will multiply them together as if they were independent, overrating the evidence. On the other hand, the LR is much more strong to correlated variables; if two features (A) and (B) are faultlessly correlated, LR will only allocate half the weight to w(A) and a half to w(B). Thus, when there are various correlated variables, LR will simply allocate a more precise probability than the SVM and naïve-Bayes. This LR is better than many other data mining methods in the small and large dataset [19], [20]. These reasons prompted the investigation and examination of the LR in spam email filtering.

TABLE. I. Spam Detection based on ML

Study	ML algorithms	Advantages
Marsono et al. [9]	Naïve Bayes	Filtering spam based on layer processing, without any requirement for reassembling.
W. El-Kharashi et al. [10]	Naïve Bayesian inference engine	Categorizing more than 117 million features per-second based on probability inputs
Y. Tang et al. [11]	SVM	SVM technique is precise and faster than the Random Forests (RF) algorithm
Silva et al. [13]	Neural network algorithm	Investigating how different groups of features influence the filtering accuracy rate
Yoo, S., et al. [12]	Priority E-mail Personalized technique (PEP)	Analyzing the personal social networks to detect user groups and to achieve the user viewpoint based on the user social roles and then applying them for email message classification
Largilliere and Peyronnet [15]	Combination approach for internet email spamming	PageRank method
Liu et al. [16]	A hybrid machine learning system aided by user-behavior to filter spam pages	Features of user behavior for distinguishing spam and non-spam pages.
Castilho et al. [17] & Rungsawang et al. [18]	Content-based features method	Extracting both link features and content for spam filtering pages with some improving email spam detection using ant colony optimization method and the topology of the web-graph

III. PROPOSED MODEL AND OPERATIONAL SYSTEM

The presented improved model and its constituent systems upgraded strategies in current circumstances have broad achievement in numerous true complex critical thinking. The significance of a joint system is not debatable, in light of the way that an individual system has its shortcoming, and an enhanced system is intended to complement the shortcoming of these individual shrewd systems. A brilliant mix of two-step bunching calculation and strategic relapse strategy is researched keeping in mind the end goal to compliment the parameters of every segment of the system. This is work by utilizing the benefits of an individual system against its inconveniences while lifting each powerless segment individual from both systems to accomplish dependability, consistency and a precise keen system extendable for utilization in grouping. The proposed enhanced system is utilized to shape a superior enhanced system with weighted elements in light of highlight weight handle.

This proposed method combined with different techniques such as Two-step clustering algorithm and logistic regression. The integrated techniques are then applied through several steps such as pre-processing (dividing the dataset into training and testing data) and weighing each feature based on the average values that can generate from each feature. The proposed system model is demonstrated in Fig. 1.

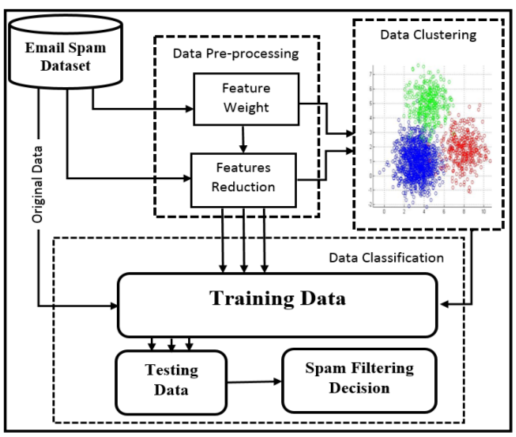

Fig. 1. Proposed system model.

A. Data Pre-processing

Pre-processing is one of the important data mining steps to prepare the dataset before the mining procedure. In this study, data preparation was used (and the dataset were divided into training and testing part), feature weight and feature reduction were based on feature weight step as three initial phases in this stage.

For preparing the dataset, there are several benchmark datasets for email spam classification and clustering roles [21]. One of this dataset is called Spam based which was reported by UCI Machine Learning repository and used in the spam filtering research such as [22], [23]. The main function of this dataset is to test and classify email messages to spam and non-spam messages. The spam based data is collected of 4,601 e-mails messages with 39.4 % (1,813) messages marked as Spam and 60.6 % (2,788) reported as non-spam [24].

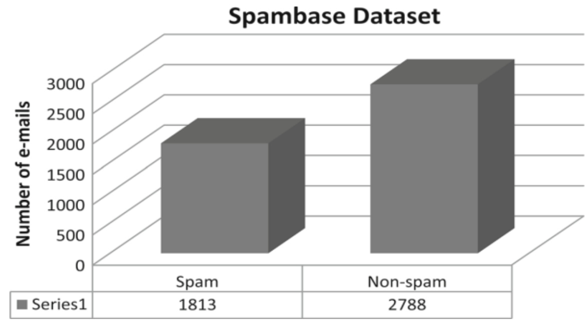

Fig. 2. Dataset distribution to spam and non-spam emails.

Fig. 2 shows the investigation of e-mail messages (spam and non-spam). In the proposed method using two-step clustering and logistic regression, the dataset was divided into 10 parts as 10-fold validation to examine the variation of the whole dataset. These parts employed for training and testing data. Each part consists of 460 instances except the last part, which consists of 461 instances. The proposed method was evaluated 10 times with each time nine parts employed as training dataset and one part considered as testing. In each round, it was considered that the testing part will be replaced with one of the nine training parts of the test and each part are done separately.

A combination of two-step clustering and logistic regression was conducted for training classifiers using the generated spam and non-spam features to filter the testing sample.

B. Data Clustering using Two-Step Algorithm

The two-step clustering technique is connected to wildcat algorithm developed to reveal natural groups inside a data set that might or not be clear [25]. The algorithm employed by this procedure has many captivating options that discriminate it from ancient clustering approaches:

- Ability to produce clusters in a continuous and categorical data type.
- The algorithm can control the generated clusters automatically.
- Ability to interact with a huge dataset probably.

C. Clustering Fundamental

The two-step technique uses distance criteria to handle continuous and categorical dataset. The likelihood considers that the data variables in the cluster system are freelance. Also, each categorical data is intended to own a multinomial distribution, and each continuous data is predictable to own a Gaussian distribution. Empirical interior testing determines that the procedure is efficiently strong to violations of each belief of independence and therefore the spatial arrangement assumptions. Conversely, it is necessary to try to remember that some of these assumptions are met. The two-steps of the technique’s rule are summarized as follows:

- **First Step.** Pre-clustering the instances (or cases) into many small sub-groups. The procedure begins with the development of a Cluster Feature (CF) Tree. The tree starts by placing the first instance at the root in a leaf node that carries variable information for that instance. Every consecutive instance is then additional to associate present node or forms a new node according to the similarity between the current nodes.

- **Step 2.** Cluster the sub-groups resulting from pre-clustering step into the coveted number of groups. It can also choose the cluster number automatically. By using agglomerative clustering (AC) approach, the leaf nodes of the Cluster Features tree are then grouped. The AC can be conducted to range the produced solutions. The optimum number of clusters can be specified by comparing these clusters based on the Akaike Information Criterion (AIC) or Schwarz's Bayesian Criterion (BIC). The similarity scores between items calculated using an Euclidean distance measure that is described in (1).

$$\text{Dist}\,(x, y) = \sqrt{\sum_{i=1}^{n} (x_i - y_i)^2} \qquad (1)$$

```
Algorithm Two-step Clustering
Input:
          //A Set X of object {X1,…Xn}
          //A distance function dist(C1, C2)
Output:
         //A Set X of clusters object {X1,…Xn}
     For i = 1 to n
         Ci={Xi}
     End for
     C={C1,…,Cn}
       I=n+1
     While C.size > 1 do
           (Cmin1, Cmin2)= minimum dist(Ci,Cj) for all Ci,Cj in C
           Remove Cmin1 and Cmin2 from C
           Add {Cmin1, Cmin2} to C
           I = I+1
    End While
```

An Euclidean vector is the position of a point in a likelihood n-space. Therefore, X is (Xn, Xn, … , Xn) and Y is (Y1, Y2, … , Yn) are likelihood vectors, starting from the origin of the space, and two points are indicated by their tips [26]. The Two-step algorithm process is demonstrated as above.

The distribution of the email messages and clustering representation process using two-step clustering algorithm is demonstrated in Fig. 3.

Fig. 3 represents the clustering output using the two-step clustering method to cross the spam dataset. It was observed that the number of extracted clusters is 3. One of the advantages of the two-step clustering algorithm is that it has the ability to determine the number of clusters automatically. An observation was noted that the size of the small cluster is cluster 3 with 253 (5.5%) email messages distribution ratio. On the other hand, the largest cluster size is cluster 1 with 3524 (76.6). The ratio of cluster 1 to cluster 3 is 13.93%. A new feature labeled as cluster represents the output of these clusters. By this feature, we can integrate the clustering algorithm with another mining method for a possible improvement reason.

Size of Smallest Cluster	253 (5.5%)
Size of Largest Cluster	3524 (76.6%)
Ratio of Sizes: Largest Cluster to Smallest Cluster	13.93

Fig. 3. Clustering results using the two-step clustering method.

D. Data Classification using Logistic Regression

Logistic regression is considered as one of the important statistical methods for investigating data in which there is one or more autonomous feature that defines results. The results are measured with a dichotomous feature, which means that the possible outcomes are two only. Based on the logistic regression mechanism, the dependent variable can be dichotomous or binary. For example, the data can only be coded as 1 (positive, Spam, Malware, detect, etc.) or 0 (negative, non-spam, non-malware, not detected, etc.). One of the main aims of the logistic regression is to find the optimum fitting model to represent the association between a set of predictor (independent) features and the interest dichotomous characteristic. Logistic regression extracts the significance levels and standard faults named coefficient values. The equation to classify a logic transformation probability of occurrence of the interested characteristic formulates as:

$$\text{odds} = \frac{\mathrm{p}}{1-\mathrm{p}} = \frac{\text{Probability of presence of characteristic}}{\text{Probability of absence of characteristic}} \qquad (2)$$

And

$$\text{logit}(\mathrm{p}) = \ln\left(\frac{\mathrm{p}}{1-\mathrm{p}}\right) \qquad (3)$$

In the classification based on logistic regression, only two classes y = 0, and y = 1 is formulated. A parametric form of P(y = 1 | x, w) is considered where w is the parameter vector.

$$\mathrm{P}(\,y = 1 \mid \mathrm{X}; \mathrm{W}\,) = \mathrm{P}_1(\mathrm{X}) = \frac{1}{1+\mathrm{e}^{-\mathrm{w.x}}} \qquad (4)$$

$$\mathrm{P}(\,y = 0 \mid \mathrm{X}; \mathrm{W}\,) = 1 - \mathrm{P}_1(\mathrm{X}) \qquad (5)$$

It is informal to illustrate that this is equivalent to

$$\log = \frac{\mathrm{P}(\,y = 1 \mid \mathrm{X}; \mathrm{W}\,)}{\mathrm{P}(\,y = 0 \mid \mathrm{X}; \mathrm{W}\,)} = \mathrm{W.X} \qquad (6)$$

The log odds of class 1 are a linear function of x as an example.

The proposed method used the discussed classifier using logistic regression to classify and filter the email into spam and non-spam. The experimental design based on the logistic regression will be discussed in the next section.

IV. Experimental Design

This experiment aimed to detect and filter the spam and non-spam messages from the email messages. The experiments were implemented on 4061 email messages, each message located as spam or non-spam according to the Spambase dataset. A method was executed by searching for the spam and non-spam email messages within the original dataset.

The spam dataset was broken down into 10 sets. Each set had a certain number of instances (email messages). The instances increased for each set with each weighting test round, starting with 460 email messages in the first set. Then, adding 460 more instances to the first set, and then, multiplying the amount of the data by 2, 3, 4, … 10 for the second set, third set, fourth set, to the tenth set, respectively. The objective of this grouping procedure was to study the pattern of the spammer user for each message so it can be focused. The average value of each of the features in the dataset was calculated as a first stage and it was noted that some of the features conveyed a very small value or had inverse proportion and some of them had a direct proportion between the number of instances and the feature values when the average was calculated. These pointers reflected the increasing and decreasing weighted score between the email features and the pattern of the spammer writing style. Possible hypothesis about this assumption was seen as a threshold for selecting the important features from unimportant features. The significant features were then nominated to enter the second training and testing experiment process. Conversely, the features that had a reverse proportion were ignored.

Training and Testing were implemented once again after features selection. The accuracy was declining as compared to the first experiment which caused the degree of learning depending on the number of significant features extracted from the email messages, and the decreasing of insignificant feature consequently led to the rise of the filtering accuracy and vice versa. The accuracy score was computed, and then the Spam base dataset was employed for training and testing process. The significant features that were selected based on the weighted process are shown in Table 2.

Table 2 demonstrates the sample results across the group of instances (messages). We have 57 features represented in each email message, and one feature named (class) represents the type of suspected message either spam or non-spam. According to the average values of these features, it was observed that several features conveyed a very small value or had inverse proportion. This score indicates that the feature is unimportant or not effectively on the filtering process of spam and non-spam. On the other hand, the significant features were reported in Table 2. This table represents features that had a direct proportion and definitely can affect the classification result by filtering the email messages to spam or non-spam. The weighting for each feature were computed to improve the achieved results that were obtained in Table 4 according to the following formula:

$$\mathrm{WF_i} = \frac{\sum \mathrm{F(i)}}{\mathrm{F(i)}} \qquad (7)$$

Where, WF_i = the weight of feature in the instance I; F(i)= Total number of values in feature i; i = (406, 920, 1380, 1840, 2300, 2760, 3220, 3680, 4140, and 4601). After the improvement process using feature weight, the effect of the weight enforcing the observation in inverse and direct proportion was observed.

TABLE. II. Significant Features

Feature ID	Average Weighted Values	Feature Rank	Feature ID	Average Weighted Values	Feature Rank
Feature 57	382.8014319	1	Feature 7	0.200511475	16
Feature 56	78.93747246	2	Feature 45	0.191798894	17
Feature 55	7.735299963	3	Feature 2	0.185727953	18
Feature 19	1.912533257	4	Feature 23	0.17626928	19
Feature 21	1.103635778	5	Feature 22	0.1670505	20
Feature 12	0.553360017	6	Feature 26	0.159371485	21
Feature 5	0.421804941	7	Feature 8	0.156010777	22
Feature 27	0.383728656	8	Feature 24	0.149887429	23
Feature 52	0.379102803	9	Feature 20	0.149717065	24
Feature 16	0.374121694	10	Feature 6	0.133869627	25
Feature 25	0.349365515	11	Feature 9	0.131386474	26
Feature 3	0.340623222	12	Feature 53	0.124596921	27
Feature 10	0.285855432	13	Feature 50	0.123808543	28
Feature 18	0.249953756	14	Feature 13	0.115471878	29
Feature 17	0.220250244	15	Feature 4	0.106688987	30

V. Results and Discussion

In this study, the experiments were built based on two types (original and weighted) spam datasets. The original dataset is the common spam data that was normally used in spam filtering research, while the weighted dataset is generated from the original dataset (Spambase) by calculating the average of each feature inside the original data. The reason for the weighted data is to study the pattern of the spammer for each feature and distinguish it as a significant or non-significant. Thus, the voted features that were selected based on the weighted process only can be used for spam filtering. By selecting the important features, the spam filtering performance will increase due to the features reduction that occurred by weighting process. To classify and filter the email messages, different types of an empirical study based on logistic regression and two-step clustering algorithm were conducted. The results that were generated behind the hypothesis will be presented in different phases: Logistic regression with all features in the dataset, logistic regression based on important features only, hybrid two-step and logistic regression with all Spam base feature datasets and the combined two-step with logistic regression based on important features that were extracted using feature weight process. The filtering accuracy computed based on the equation:

$$\text{Accuracy} = \frac{(\text{TN} + \text{TP})}{(\text{TN} + \text{FP}) + (\text{TP} + \text{FN})} \times 100 \qquad (8)$$

Where,

True Positive (TP): The number of spam and non-spam emails executable correctly classified; False Positive (FP): The number of spam executable classified as non-spam; True Negative (TN): The number of spam and non-spam executable incorrectly classified; False Negative (FN): The number of non-spam executable classified as spam emails.

The results of emails filtering using logistic regression methods based on dataset features and important features are illustrated in Tables 3 and 4, respectively.

The tables show the results of 10-fold cross validation to examine all the parts of the dataset. Each part implemented in one round from round 1 to round 10. For each experimental round, nine parts represent a training dataset while the remainder part (only one part) represents a testing dataset. The testing part is becoming one of the training datasets during each experiment. The total results are an equal average value for all the ten parts. These results represent the filtering accuracy of the training and testing data, the misfiltering ratio, the area under the carafe, and the number of correct filtering messages to spam and non-spam in the dataset.

TABLE. III. Result of Logistic Regression with All Features in the Dataset

Dataset Round	Classification Accuracy TP/FN		Misclassification Accuracy TN / FP		Area under the Carafe		Number of corrected filtered email messages			
	Training	Testing	Training	Testing	Training	Testing	Training Spam	Training Non-Spam	Testing Spam	Testing Non-Spam
Round 1	90.51%	95.87%	9.49%	4.13%	0.962	0.991	3,748	393	441	19
Round 2	90.51%	94.78%	9.49%	5.22%	0.963	0.976	3,748	393	436	24
Round 3	90.80%	93.48%	9.20%	6.52%	0.962	0.981	3,760	381	430	30
Round 4	90.17%	95%	9.83%	5%	0.961	0.990	3,734	407	437	23
Round 5	91%	96.30%	9%	3.70%	0.962	0.993	3,749	392	443	17
Round 6	90.75%	94.57%	9.25%	5.43%	0.964	0.986	3,758	383	435	25
Round 7	90.22%	100%	9.78%	0.00%	0.959	1	3,736	405	460	0
Round 8	90.85%	95.43%	9.15%	4.57%	0.962	0.991	3,762	379	439	21
Round 9	91.23%	93.26%	8.77%	6.74%	0.966	0.976	3,778	363	429	31
Round1 0	92.44%	90.89%	7.56%	9.11%	0.971	0.968	3,827	313	419	42
Average	90.85%	94.96%	9.15%	5.04%	0.96.36	0.98.57	3760	380.9	436.9	23.2

TABLE. IV. Result of Logistic Regression with Important Features

Dataset Round	Classification Accuracy TP/FN		Misclassification Accuracy TN / FP		Area under the Carafe		Number of corrected filtered email messages			
	Training	Testing	Training	Testing	Training	Testing	Training Spam	Training Non-Spam	Testing Spam	Testing Non-Spam
Round 1	92.8%	90.22%	7.17%	9.78%	0.977	0.999	3,844	297	415	45
Round 2	92.97%	97.17%	7.03%	0.0283	0.976	0.990	3850	291	447	13
Round 3	93.19%	95.87%	6.81%	0.0413	0.976	0.995	3859	282	441	19
Round 4	92.71%	96.74%	7.29%	0.0326	0.974	0.997	3839	302	445	15
Round 5	93%	98.7%	7%	0.013	0.976	0.998	3851	290	454	6
Round 6	92.95%	96.96%	7.05%	0.0304	0.977	0.998	3849	292	446	14
Round 7	92.44%	99.35%	7.56%	0.0065	0.973	0.999	3828	313	457	3
Round 8	92.54%	99.57%	7.46%	0.0043	0.975	1	3832	309	458	2
Round 9	93.53%	94.57%	6.47%	0.0543	0.978	0.993	3873	268	435	25
Round1 0	94.15%	95.66%	5.85%	0.0434	0.981	0.992	3898	242	441	20
Average	93.03%	96.48%	6.97%	3.52%	0.97.68	0.9961	3852.3	288.6	443.9	16.2

In Table 2, it was observed that the achieved results on the 30 important features excluding the target feature (Class) are better than using all the dataset features. This indicates that the selected features are more significant. Also, the process time will be reduced accordingly because only the important features extracted will be tested rather than all features. Another criterion that was used for evaluating the proposed method is the Area under carafe (AUC). It is an assessment metric normally used in binary classification challenge. When the accuracy computed based on the true and false positive rate as the threshold rate for classifying an element as 0 or 1: if the predictor is best, the true positive ratio will rise rapidly, and the AUC will be close to 1. On the other hand, if the predictor is less than the random predicting, the true positive ratio will rise linearly with the false positive ratio and the AUC will be around 0.5 [27], [28]. AUC metric is important because it can evaluate the predictor's performance on the unbalanced dataset. It is independent of the fraction, of the test population, which is, target, class one, or zero. However, the spam and non-spam dataset that was used is not equivalent. The AUC results represented in Table 4 indicate that the performance evaluation is enforcing the filtering accuracy results and proved better results after weighting process and feature selection.

TABLE. V. RESULT OF HYBRID TWO-STEP AND LOGISTIC REGRESSION WITH ALL SPAM BASE FEATURES DATASET

Dataset Round	Classification Accuracy TP/FN		Misclassification Accuracy TN / FP		Area under the Carafe		Number of corrected filtered email messages			
							Training		Testing	
	Training	Testing	Training	Testing	Training	Testing	Spam	Non-Spam	Spam	Non-Spam
Round 1	97.33%	98.35%	2.67%	1.65%	0.986	0.989	4,072	69	457	3
Round 2	97.53%	95.96%	2.47%	4.04%	0.987	0.989	4,080	61	446	14
Round 3	97.12%	97.48%	2.88%	2.52%	0.986	0.989	4,063	78	453	7
Round 4	97.14%	98.57%	2.86%	1.43%	0.986	0.99	4,064	77	458	2
Round 5	97%	98.13%	3%	1.87%	0.986	0.989	4,070	71	456	4
Round 6	97.33%	96.39%	2.67%	3.61%	0.986	0.989	4,072	69	448	12
Round 7	97.14%	98%	2.86%	2.00%	0.986	0.989	4,064	77	455	5
Round 8	97.21%	96.83%	2.79%	3.17%	0.987	0.989	4,067	74	450	10
Round 9	97.26%	97.70%	2.74%	2.30%	0.986	0.989	4,069	72	454	6
Round1 0	97.53%	96.61%	2.47%	3.39%	0.987	0.989	4,079	61	450	11
Average	97.26%	97.40%	2.74%	2.60%	0.9863	0.9891	4070	70.9	452.7	7.4

TABLE. VI. RESULTS OF COMBINED TWO-STEP WITH LOGISTIC REGRESSION BASED ON IMPORTANT FEATURES

Dataset Round	Classification Accuracy TP/FN		Misclassification Accuracy TN / FP		Area under the Carafe		Number of corrected filtered email messages			
							Training		Testing	
	Training	Testing	Training	Testing	Training	Testing	Spam	Non-Spam	Spam	Non-Spam
Round 1	98.33%	99.35%	1.67%	0.65%	0.996	0.999	4,072	69	457	3
Round 2	98.53%	96.96%	1.47%	3.04%	0.997	0.999	4,080	61	446	14
Round 3	98.12%	98.48%	1.88%	1.52%	0.996	0.999	4,063	78	453	7
Round 4	98.33%	99.57%	1.67%	0.43%	0.996	1	4,073	68	458	2
Round 5	98%	99.13%	2%	0.87%	0.996	0.999	4,070	71	456	4
Round 6	98.33%	97.39%	1.67%	2.61%	0.996	0.999	4,072	69	448	12
Round 7	98.50%	98.26%	1.50%	1.74%	0.996	0.999	4,080	61	452	8
Round 8	98.55%	97.83%	1.45%	2.17%	0.997	0.999	4,082	59	450	10
Round 9	98.48%	98.48%	1.52%	1.52%	0.996	0.999	4,079	62	4,079	63
Round10	98.89%	98.26%	1.11%	1.74%	0.997	0.999	4,095	45	453	8
Average	98.41%	98.37%	1.59%	1.63%	0.999	0.999	4076.6	64.3	815.2	13.1

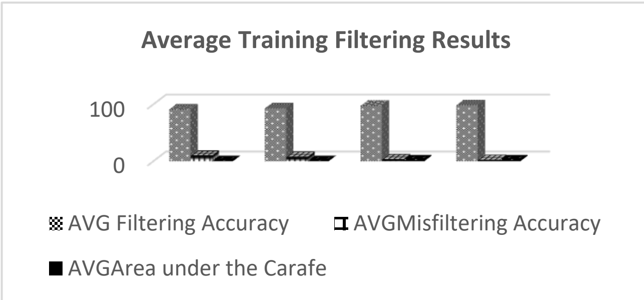

Fig. 4. Average training results of emails spam filtering experiments.

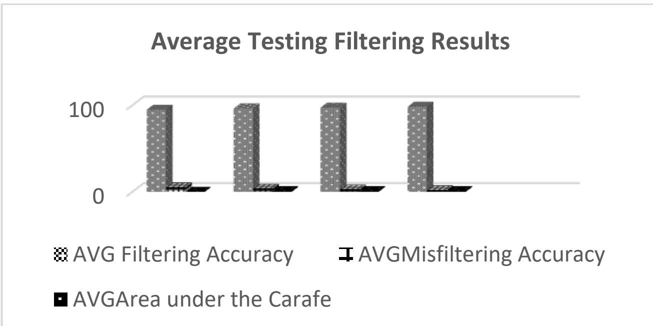

Fig. 5. Average testing results of emails spam filtering experiments.

Fig. 4 and 5 represent the average training output of the spam email filtering before and after feature selection using feature weight process. The dataset was examined based on two techniques; the logistic regression and the combined technique between logistic regression and two-step clustering algorithm. Table 3 presents the prediction of email filtering using the logistic regression method extracted average accuracy results with 90.8% for training phase and 94.96% for testing phase before feature weighting process. However, average accuracy results represented in Table 4 with 93.03% in the training phase and 96.48 % in the testing phase after selecting significant features using feature weight process were achieved. On the other hand, Tables 5 and 6 illustrates the prediction of email filtering using hybrid logistic regression and the two-step clustering algorithm obtained average accuracy result at 97.26% and 97.40% before feature weighting process for training and testing phases respectively. The average accuracy results after selecting significant features using feature weight process, obtained 98.41% and 98.37% for training and testing phases, respectively.

To explore the differences between this study's spam filtering technique based on the logistic regression and two-step clustering algorithms before and after improvement using weighting process and important features, an Independent Sample T-test was performed such as [29]. The achieved values can be significant if the result is below 0.05. In Table 7 the significant values are (0.006) between this study's combined LR-Two-step and LR before feature weight, and (0.0007) between the combined LR-Two-step and LR after feature weight, this indicates that the combined method reached significant enhancement on the accuracy results. Thus, a conclusion was drawn that there is a significant difference before and after feature weight and combination process. Table 7 shows the T-test statistical significance results.

Another comparison between this study's integrated technique and current approaches demonstrates in Table 8, Fig. 6 and 7. It was noted that the combined method between the logistic regression and Two-step clustering algorithm obtained best accuracy results based on both all features, and important features in the spam based dataset.

TABLE. VII. T-TEST STATISTICAL SIGNIFICANCE RESULTS

Method	**Differences between accuracy result before and after the improvement**					**T**	**Sig. Value**
	Mean	**Std. Deviation**	**Std. Error Mean**	**95% Confidence Interval of the Difference**			
				Lower	Upper		
LR & LR-Two-Step (Before feature weight)	-2.444	2.150	.680	-3.982	-.906	-3.594	.006
LR & LR-Two-Step (After feature weight)	-.969	.335	.106	-1.209	-.729	-9.152	0.0007

TABLE. VIII. A COMPARISON OF THE PROPOSED METHODS AND OTHER SPAM FILTERING METHODS

Method	**Results using All Features**		**Results using Important Features**	
	Accuracy	**Error**	**Accuracy**	**Error**
Logistic Regression	**90.85%**	**9.15%**	**93.03**	**6.97**
Logistic Regression-Two-step	**93.03%**	**6.97%**	**98.41**	**1.59**
SVM [11]	90%	10%	89.34	10.66
naive Bayes [9]	78.8%	21.2%	83.17	16.83
Neural Network [13]	94.30%	5.694%	94.2	5.8
k-nearest neighbor [31]	90.8%	9.2%	88.4	11.6

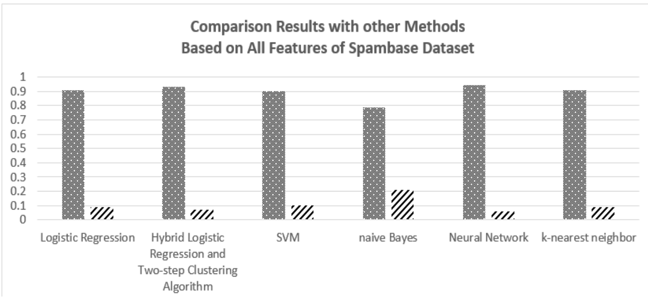

Fig. 6. A comparison between this study's proposed methods and other spam filtering methods based on all features.

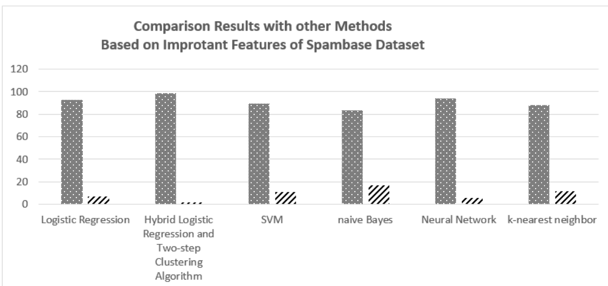

Fig. 7. A comparison of this study's proposed methods and other spam filtering methods based on important features.

Fig. 6 and 7 represent the comparison result between the proposed method and current spam classification methods. In Fig. 6, the comparison based on all spam features of spam based dataset, while Fig. 7 represents the comparison of results based on significant features that were extracted using weight feature process. It was observed that the proposed LR-two-step technique achieved the best result using both dataset features and significant features. On the other hand, the lower result was obtained by the naive Bayes method as shown in Table 8.

VI. Conclusion

This study is considered one of the main challenges through the email messages. The spammers can easily steal information by sending random spam emails via the internet. This research tried to investigate the email messages based on the logistic regression method to classify the messages to spam or non-spam. A feature weight based on the amount of data is one of the contributing parts proposed in this study to select the significant features. Another contribution is an integrated technique between the logistic regression and two-step clustering method to differentiate the email messages of spam from non-spam. The benefit of using the two-step clustering method is to group the similar emails features to study the spammers' pattern by focusing on their beavering in constructing the email messages. The proposed method used a UCI Spam base dataset to build the spam-filtering model. Based on the obtained results, conclusions were made that not all the email messages writing style features could be used by spammers. Where, only the important features that were selected using feature weight process can improve the computational time of email spam filtering. The proposed method was tested using T-test statistical significant method to prove improvement before and after feature selection and combination process. It has been shown that the LR-Two-Step can significantly enhance the filtering accuracy ratio and decrease the misfiltering error in spam dataset.

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A Novel Unsupervised Abnormal Event Identification Mechanism for Analysis of Crowded Scene

Dr. Pushpa D
Department of Information Science and Engineering,
Maharaja Institute of Technology, Mysuru, India

***Abstract*—The advancement of visual sensing has introduced better capturing of the discrete information from a complex, crowded scene for assisting in the analysis. However, after reviewing existing system, we find that majority of the work carried out till date is associated with significant problems in modeling event detection as well as reviewing abnormality of the given scene. Therefore, the proposed system introduces a model that is capable of identifying the degree of abnormality for an event captured on the crowded scene using unsupervised training methodology. The proposed system contributes to developing a novel region-wise repository to extract the contextual information about the discrete-event for a given scene. The study outcome shows highly improved the balance between the computational time and overall accuracy as compared to the majority of the standard research work emphasizing on event detection.**

***Keywords*—Abnormal event; detection; event detection; object detection; machine learning; video surveillance**

I. Introduction

With the evolution of visual sensors, the security and monitoring based application has been consistently witnessing revolution [1]. Such advanced forms of image capturing devices offers enhanced capability to obtain various scenic information but is also shrouded by various loopholes. The first problem lies in identifying the moving objects on the given scene. At present, there are various research work that has contributed towards object detection, tracking, and counting [2] but none of these actually existing in commercial application of global market at this time. We find that there is a bigger gap between the research papers and application existing in real-time scenario [3]. The existing research work claims of using sophisticated theory and technologies to perform extra-ordination tracking and identification of an object but in real-time environment there are various applications which have never seen such implementations ever. Some of the impediments towards object detection widely studied are uncertain and dynamic mobility pattern, occlusion pattern, illumination issues, etc. [3]. Existing research work has also reported the usage of single and multi-camera in order to perform tracking and identification of an object. However, this is not at all an easier task to perform recognition of an object with higher accuracy. Hence, adoption of machine learning mechanism has become inevitable in this regards [4]. The contribution of machine learning approach is to offer more decision making for better identification, classification, and clustering operation in object detection [5]. However, there is also another field of advancement in object detection i.e. event detection which is a superset of object detection [6]. Majority of the implementation of object detection focuses more on foreground while event detection mechanism requires equal emphasis on both foreground and background to understand [7]. Still, the process of event detection is quite a challenging task because of following research question viz. 1) how to model an event discretely. We have observed that various researchers have modeled the event considering the supervised learning algorithm with higher emphasis on accuracy in identification process [8]. However, we find that accuracy is not found to be much better keeping it in balance with the computational demands. This process of event detection becomes further more challenging if the criticality of the event has to be determined. From application viewpoint, it is essential for the application to take decision based on the context of the scene, which is another challenging task [9]. It is because there are multiple forms of uncertainty associated in extracting contextual information from the event detection. Hence, the flow of the application design should be to prioritize on object detection followed by identification of possible event-based information and then to work on extracting amount of abnormality to confirm the context of the scene [10]. Hence, abnormality over the event-based information is one of the most important decision-making factors towards confirming false or true positive of the object detection.

Therefore, the proposed system discusses a novel modeling of a system that is capable of precisely identifying the abnormality of an event from a regular crowded scene. The significant novelty of the proposed system is to model an unsupervised learning technique and usage of a repository system that offers a superior mapping policy of the extracted regions for better identification performance.

The next Section II presents a discussion on related works followed by brief outlining of associated problems in it in Section III. Research methodology adopted to solve the problem is discussed in Section IV followed by an illustration of Algorithm implementation in Section V. Results obtained and discussion of the graphical outcome is carried out in Section VI and finally the conclusive remarks is given in Section VII.

II. Related Techniques

This section discusses the existing approaches that deal with the investigation of the mobility behavior of an object on various scenarios. Existing techniques have witnessed usage of conventional object detection schemes that are quite high in number followed by research towards event detection method and abnormal event detection mechanism.

The work carried out by Cao et al. [11] has used total variation method where a spatial continuity based approach is used for marking foreground. The outcome has exhibited a promising accuracy performance. Guan et al. [12] have used a dictionary-based mechanism (i.e., a bag of words) to perform detection of the objects in the road using semantics. However, the technique consumes maximum time for processing the outcome. Hu et al. [13] have used saliency features and low ranking representation to perform identification of moving object. Although the technique is highly comprehensive for moving object detection, it offers complexity. Kelantan et al. [14] have emphasized on identifying moving objects in multiple numbers using adjacency graphs. The system has used multi-graph matching policy as well as used labeling of the regions to perform detection of objects. Kang and Zhu [15] have adopted compressive sensing mechanism where circulate sampling mechanism is used for obtaining samples followed by a typical reconstruction method of the foreground. Usage of search optimization method is a witness in work carried out by Lee et al. [16]. The authors have constructed saliency map using a genetic algorithm to track the movement of an object. Tested on three different datasets, the outcome showed more than 94% of accuracy. Luo and Lai [17] have used localization factor as well as mapping attribute to perform identification of a moving object. The study contributes to the identification of an object from different image feed extracted from multiple sensors. Panda and Meher [18] have presented a technique for background subtraction using color difference histogram to control false errors. The authors have also used a fuzzy c-means algorithm to minimize the dimensionality problems associated with histogram computation. Park et al. [19] have presented a k-nearest clustering mechanism on stereo images for identification of moving object. Adoption of a temporal factor is reported in the research carried out by Wang et al. [20] where the detection model is completely free from any dependencies on background modeling. The technique uses entropy and uses saliency map to perform identification of an object. Wu et al. [21] have used subtraction mechanism for background using singular value decomposition followed by adaptive thresholding. The technique uses fast in painting for reconstructing an image. Yeh et al. [22] have used hysteresis threshold technique to perform identification of mobile objects. Incorporation of the pyramidal feature is seen in the work carried out by Yuan et al. [23]. The presented paper has used the magnitude of difference and structural description of specific context. The work entirely emphasizes on the feature section process to find lesser processing time involved. Usage of Bayesian approach for a similar reason was seen in the work of Zhang et al. [24].

Literature has a good amount of work towards object detection system; however, there are also certain closer attempts towards event detection system. A study in such direction was carried out by Cosar et al. [25] where both problems of analysis of behavior as well as abnormal detection of behavior are jointly addressed using trajectory and pixel-based information. The technique also implements clustering mechanism on the analyzed grid to perform detection. Wang and Ji [26] have presented a machine learning approach along with semantics to perform event recognition. A priming contextual framework is designed for this purpose. Wen et al. [27] have implemented the standard Gaussian model to obtain better tracking points for better response timing of event detection. A simple optimization process towards object detection is presented for better optical flow. Xian et al. [28] have used Fisher Vector to perform extraction of features (low-level) to perform event detection using the random forest. A standard test-bed is utilized to perform the assessment. There is very less number of studies that have focused on event detection in recent times.

Still, some of the researchers have tried their best to consider the further challenging problem of abnormality involved in event detection. Bae et al. [29] have presented a technique of identifying abnormal mobility of an object using partial trajectory-based information from the cluttered scene. However, the accuracy is not found to have better improvement irrespective of a better approach. Similar problems have been addressed by Chen et al. [30] using a non-conventional acceleration based framework. However, the technique cannot support the dynamic response of detection required for real-time performance. Fu et al. [31] have used feature learning system to identify the trajectories of an object. The presented technique is used for minimizing the space of search as well as a collaborative algorithm is presented to enhance the accuracy performance of abnormality detection process. Wang and Snoussi [32] have presented a unique classification technique using a conventional supervised learning algorithm to perform identification of the abnormal event. Tao et al. [33] have used semantics to perform identification of an abnormal event for a given scene using slow feature analysis. Zhang et al. [34] have considered compression and detection problem together on multimedia contents. Levy et al. [35] have developed a dataset that is meant for experimenting various identification of abnormal events in real-time. The work carried out by Yu et al. [36] has used sparsity-based approach along with gradient feature to offer better reconstruction method. The next section discusses problems being identified from existing literature.

III. Problem Identification

The identified problems after reviewing the existing system on object and event detection are as follows:

- *Lesser Improvement in Abnormal Movement Modeling*: Majority of the existing study has no direct representation or standard definition of the abnormal event in object detection. The abnormality is a contextual term associated with the occurrence of the less probable appearance of object behavior for a given scene. Existing implementation ignores modernizing the techniques in the object detection scheme and directly works on event detection and hence the granularity in detection performance misses out.
- *More Focus on Accuracy and Less on Complexity*: Existing schemes mainly deals with implementing either iterative or complex technique of optimization resulting in higher accuracy at the cost of complexity. The biggest complexity associated in this regard is to extract the information about the exact location which has error-free information about the abnormal events. This result is good accuracy performance and lower

complexity mitigation performance at the same time. This also results in a lower response time of the detection, which makes it less suitable for online schemes.

- *Less Utilization of Spatio-Temporal Factor*: Usage of time and space-related factors are very useful to understand the optical flow of an object. However, the mathematical modeling has the lesser inclusion of these factors jointly those results in ignorance towards the timely response of the identification modeling. This operation of emphasizing any one of the factors results in better accuracy but lowers down response time.
- *Dominancy of Supervised Algorithm*: Usage of supervised algorithms offers good convergence performance and better flexibility of achieving research goals; however, they also offer uncertainty to be applied in a real-time environment. On the other hand, adoption of unsupervised learning algorithms is quite challenging to build but once built than they can also be used for online or real-time environmental usage. However, it is a computationally challenging task to develop an unsupervised learning algorithm for dynamic object detection and event modeling.

It is essential to understand that modeling of abnormal event behavior is a combined study of behavioral analysis along with event modeling. The significant research problem is to jointly model abnormality event detection along with behavioral analysis. Because there has been enough work already carried out in behavioral analysis on the crowded scene, the focus will be narrowed down to abnormality event detection. Therefore, the research problem can be stated as "*To design a framework for facilitating unsupervised modeling of abnormal event detection on a crowded scene.*"

IV. Proposed Methodology

There are multiple impediments towards identifying an object in a precise manner. Our prior implementation has offered various techniques to deal with identification, recognition, tracking related issues for various dynamic scenarios of an object [37]-[40]. This part of the proposed system contributes to deal with abnormal event detection with the dynamic mobility of an object within it. The architecture of the proposed system is highlighted in Fig. 1.

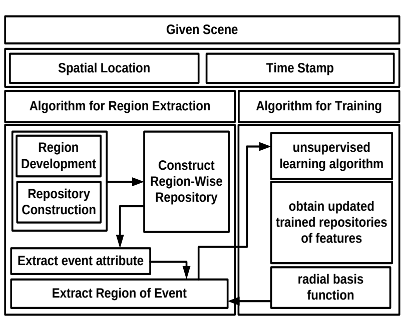

Fig. 1. Architecture of proposed abnormal event detection.

The proposed system takes the input as a given scene from where the abnormal event has to be identified. It, therefore, emphasized on the region around the object. A *region* of the proposed system is defined as all the possible section within the frame which has been captured with the abnormal event. The proposed system extracts the spatial and temporal attributes which are further subjected to two explicit algorithms for region extraction and training respectively. An empirical-based approach is utilized for developing such regions. The proposed implements a unique technique for classifying different forms of image-related attributes by considering them as string attributes called as a repository. It will mean that each specific attributes obtained dynamically obtained from the given scene are converted to strings that makes the process of classification much well structured. This process also assists in constructing region-wise repository that finally assists in extracting event attributes. However, the process of detection is finally subjected to unsupervised training process using radial basis function to further confirm the correctness of abnormal event identification. The complete training algorithm is constructed using probability theory where a statistical significance is used to determine if the identified event is significant or not. The applicability of the proposed system suits well in the crowded scene where certain behavior or pattern of object mobility is highly restricted. It could also be used for security monitoring in hospitals, dock yards, airport, mining fields to perform precise identification of any life-threatening events. The complete implementation is carried out considering an analytical research methodology where the focus is laid to the region extraction and training. The next section outlines the algorithm implemented to perform abnormal event detection.

V. Algorithm Implementation

This section outlines the algorithm implemented for the purpose of identifying the abnormality event in the given scene of object detection. The proposed study considers a definitive region under which the complete evaluation is carried out by the given frame. The first algorithm is mainly responsible for extracting the region by considering the input to be $_{size}$ (size of region), $I_{r,c}$(rsize of frame), R (region), Ω (repository) is database, I_{trn} (trained image), N (Number of Sequence), λ (size of one region) that after processing leads to the outcome of Ω (repository of the region). These parameters are helpful to capture the particular image frame from the video frame. Using this particular region is observed for abnormal behavior detection. The steps of the algorithm are as follows:

Algorithm for Region Extraction

Input: r_{size}, $I_{r,c}$, R, Ω, I_{trn}, N, λ
Output: Ω
Start
1. init r_{size}
2. get $I_{r,c}$
3. R$\rightarrow f$(I)
4. $\Omega=\{\Omega_r\ \Omega_c\ I_{trn}\}$
5. **For** i=1: N
6. construct *I*
7. $\vartheta(n, \lambda)\rightarrow$R
8. **End**
9. **For** j=1:size(ϑ)
10. **If** $\sum$e===0
11. continue;
12. **End**
13. $\vartheta\rightarrow$e/norm(e)
14. **End**
15. $\vartheta \rightarrow \Omega$
End

The above-mentioned algorithm takes the input of the sequence of images and proceeds to the construction of repository as well as region development. All the frames are read, and system initializes the image to be used for training I_{trn} (Line-1, Line-2). The size of the frames is obtained and is extracted for some rows, column, and the index number of the cells. The algorithm than classifying the given frame using a function *f* concerning equal region splits in orders to obtain core region *R* (Line-3). The next part of the algorithm is to develop a repository Ω considering sub-repository Ω_r and Ω_c, where Ω_r and Ω_c represent product of regions and size of region respectively (Line-4). The algorithm constructs region-wise repository ϑ by Ω_r and Ω_c. For all the number of frames N (Line-5), the proposed algorithm constructs region R by individual regions and size of one block λ. (Line-6). All the mean outcomes of the region-based repositories were obtained, i.e., σ=mean(ϑ). For all the size of region-based repository ϑ (Line-9), an event attribute e is extracted from all the columnar elements of region-based repository ϑ. In case there is no significant event (Line-10), the system continues to check for other regions (Line-11). The next event attribute *e* is obtained as $e \rightarrow e - \sigma(\vartheta)$ followed by normalization of event attribute (Line-13). The updated information of the event attribute is stored back in a matrix that deposits ϑ. The next part of the system is to apply the novel learning process to perform better object detection.

Algorithm for Training

Input: Ω_{size}
Output: Rep
Start
1. **For** i=1: Ω_{size}
2. H→ Ω(i)
3. Create ψ(H)
4. **For** j=1: H_{size}
5. ψ(j)=H(j)
6. **End**
7. Apply *g*(ψ) to obtain [α, β]
8. Rep→(ψ, α, β)
9. **End**
End

The outcome obtained from the prior algorithm of region extraction is used for as an input for the training process. For this purpose, a loop is constructed considering all the sizes of the repository Ω (Line-1). A temporary variable H is constructed for obtaining all the size-related information from each repository Ω (Line-2). A structure ψ is created that holds the information of sizes of matrix H (Line-3) and all the individual information retained in the matrix is transformed in a new matrix ψ (Line-5). The next part of the algorithm applies an unsupervised learning algorithm in the form of a function *g*(ψ) to obtain updated trained repositories of features, i.e., α, β (Line-7). The final construction of repository is carried out considering ψ along with α, β (Line-8). The construction of the function *g* is designed considering radial basis function as the kernel attribute. The next step is to perform detection of the abnormal event using test-frame sequence and followed by almost similar steps of selection of regions and training. However, the technique loads the repository outcomes and computes the probability of minimum distance between two data points and compared with the ground truth images. It applies the process of matrix decomposition to obtain the concatenated centroid position of the test mage followed by dilation operation on the ground truth image. Certain threshold is fixed to identify the possibilities of abnormalities on the given scene as the cumulative outcome of the proposed algorithm.

TABLE. I. LIST OF NOTATION

r_{size}	Size of the region
$I_{r,c}$	Size of the frame
R	Region
Ω / Ω_{size}	Repository, size of repository
I_{trn}	Trained image
N	Number of sequences
A	Size of one region
Rep	Trained data
e	Event attribute

VI. RESULT ANALYSIS

The proposed system is assessed considering the UCSD pedestrian dataset [41]. In this, MATLAB is used for image isolation from the video. The data set consists of more than 1000 image sequences with both test and trained images. The time frame for scene change is indicated for 15 sec/frame. Each frame shows a lane where people are found to walking in opposite direction, and their behavior of crowd cannot be predicted to a particular pattern. At the same time, we consider an event to be taken place when any object, e.g., cart, bicycle, 4-wheeler, etc. is found to be moving within the visual scope of the lane.

The implementation of the proposed study is carried in Matlab and using the similar data; the study outcome is compared with similar existing techniques dealing with event detection concerning accuracy and computation time. The existing studies compared with are the work carried out by Saligrama et al. [42] - LSA, Roshtkhari et al. [43] - ODABD, Mahadevan et al. [44] - AD, Bertini et al. [45] - NPA, and Reddy et al. [46] - CBA.

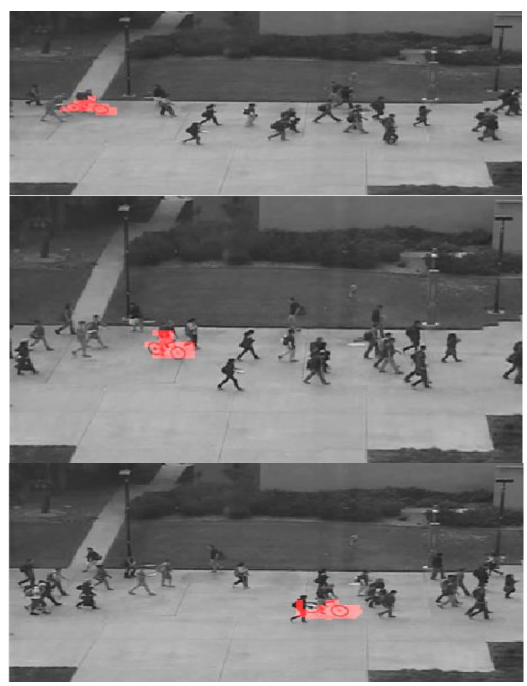

Fig. 2. Visual capturing of abnormal events.

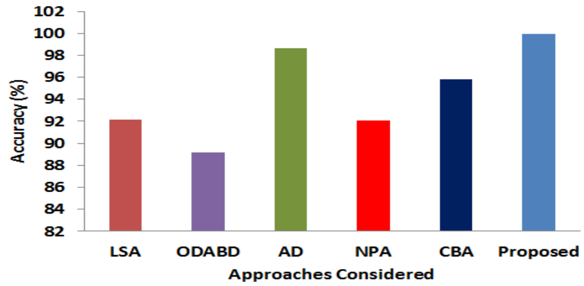

Fig. 3. Comparative analysis of accuracy.

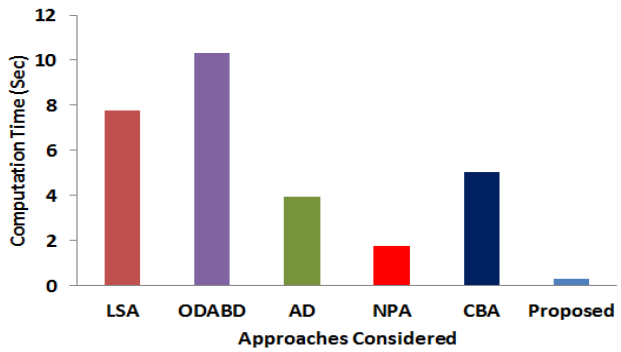

Fig. 4. Comparative analysis of computation time.

The study outcome shows that proposed system excels better event of abnormality detection performance as compared to all the existing system. The prime reason for enhanced accuracy of the proposed system is the granularity in the approach for event detection using the concept of matrix factorization. Another essential contribution is the novel learning algorithm that exploits the histogram attributes for extracting the information of any unusual object appearance for a given scene and can easily justify and segregate the usual to unusual appearance of the object. This will also mean that proposed system uses smaller time frame for computing the sophisticated behavior of the given crowded scene also. The final reason for this outcome is discrete modeling of time, and spatial attributes for better context-based information can be extracted for incorporating granularity in abnormal event detection system. At the same time, the algorithm offers faster response time in comparison to the existing system.

VII. Conclusion

With the proliferation of video surveillance system, it is quite imperative that there have been some significant proposals for the object as well as event detection scheme. However, after reviewing the existing system, we find that there are some significant problems, e.g., 1) Lesser Improvement in Abnormal Movement Modeling; 2) More Focus on Accuracy and Less on Complexity; 3) Less Utilization of Spatio-Temporal Factor; and 4) Dominancy of Supervised Algorithm. This problem leads to less emphasize on the modeling aspect of the abnormality factor, which is always regarding probability. The proposed system considers that if any alienated object is found to display a mobility behavior which is completely different from what has been captured till the time instance is called as an abnormality. A good utilization of this scheme could be to monitor the patient in coma stage. A sudden movement captured from such patient is treated as an abnormal event that prompts for alarm. Similarly, it could be used in industrial monitoring and other traffic-related monitoring system too. The presented system applies a mechanism where local patterns are emphasized on each region for a given frame using histograms. The proposed system also applies probability theory for modeling using temporal and spatial factor using unsupervised learning algorithm.

The proposed method can be used to the method can be used for surveillance system of a location, mall, military applications and this research can be used as benchmarks for further improvement in security systems.

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Validation of Semantic Discretization based Indian Weighted Diabetes Risk Score (IWDRS)

Omprakash Chandrakar
Department of Computer Science and Technology
Uka Tarsadia University, Bardoli, Gujarat, India

Jatinderkumar R. Saini
Narmada College of Computer Application
Bharuch, Gujarat, India

Lal Bihari Barik
Department of Information Systems
Faculty of Computing & Information Technology in Rabigh, King Abdulaziz University,
Kingdom of Saudi Arabia

***Abstract*—The objective of this research study is to validate Indian Weighted Diabetes Risk Score (IWDRS). The IWDRS is derived by applying the novel concept of semantic discretization based on Data Mining techniques. 311 adult participants (age > 18 years), who have been tested for diabetes using the biochemical test in pathology laboratory according to World Health Organization (WHO) guidelines, were selected for this study. These subjects were not included for deriving IWDRS tool. IWDRS is calculated for all 311 subjects. Prediction parameters, such as sensitivity and specificity are evaluated along with other performance parameters for an optimal cut-off score for IWDRS. The IWDRS tool is validated and found to be highly sensitive in diagnosing diabetes positive cases at the same time it is almost equally specific for identifying diabetes negative cases as well. The result of IWDRS is compared with the results of another two similar studies conducted for the Indian population and found it better. At optimal cut-off score IWDRS>=294, the prediction accuracy is 82.32%, while sensitivity and specificity is 82.22% and 82.44%, respectively.**

Keywords—Data mining; indian weighted diabetes risk score; semantic discretization; type-2 diabetes risk score

I. Introduction

Undetected diabetes and prediabetes are the major concerns for East Asian countries, including India [1]. In such scenario, Diabetes Risk Score (DRS) tools can be proved effective in detecting undiagnosed diabetes and pre-diabetes cases. DRS tools are simple and easy to use computational tools that calculate the risk of diabetes of an individual's based on some risk factors.

Rest of the paper is organized as follows. Section 2 presents the literature review, which is followed by the discussion on Indian Weighted Diabetes Risk Score (IWDRS) in Section 3. Section 4 presents an outline of the research design. Details of experiments and results are discussed in Sections 5 and 6, respectively. The conclusion of the research study is given in Section 6.

II. Literature Survey

Various DRS tools have been reported in literature [2]-[14]. Basically, DRS tool uses a questionnaire to collect data from the target population. These data are used to build a mathematical model for predicting risk score of an individual. A mass diabetic screening test can be organized to detect undiagnosed and pre-diabetic persons, in which only those person who scored high on DRS, will be pathologically tested for high blood sugar. Developing countries like India, where lack of awareness, lack of pathological testing facilities, shortage of medical fund and late diagnosis is a major problem, DRS tools can be used as a cost-effective solution.

Several DRS tools have been developed and validated for different ethnic groups. A DRS tool, developed for a particular ethnic group, may not be generalized and may not produce similar results if applied on another ethnic group [15]. And that is why, separate DRS tools need to be developed and validated for each ethnic group, society, and country.

Logistic regression and Cox logistic regress models are used for deriving such risk scores, in which β coefficients of the risk factors are computed [10], [11], [14]. But building such logistic regression models are not a fixed, and it cannot be reproduced. Gary et al. [16] have observed that different investigators with the same data set produced different risk models. Anderson et al. [17] have argued that the diagnostic algorithm tools developed using logistic regression model is not perfect and prone to misuse.

To overcome the limitations of logistic regression models, Chandrakar and Saini have proposed a new methodology for deriving risk score and applied for deriving IWDRS [18]. IWDRS is derived by collecting data from a comprehensive questionnaire consisting of more than 60 risk factors [19], [20]. These risk factors are discretized using a novel concept of semantic discretization [21]. Then each risk factor is assigned to appropriate weight using machine learning techniques, and the corresponding risk score is calculated. One study Pima Indian Diabetes Dataset shows that classification accuracy is significantly increased when the dataset is semantically discretized before giving them to classifier [21]. In the present study, researchers validate the proposed IWDRS.

III. Indian Weighted Diabetes Risk Score

IWDRS is developed for Indian population considering demographic, socioeconomic, family and personal indicators. It includes parameters like age, family history of diabetes, blood pressure and high cholesterol, personal history of blood pressure and high cholesterol, BMI, waist circumference, diet quality, stress, physical activity and life quality. Various types of stress faced like work stress, financial stress, family or social stress and health-related stress with its perceived intensity are considered. Life quality majors how the subject perceives the quality of his/her life, which includes qualitative indicators like happiness, love, and hope in their life. Responses of these parameters recorded at three different points of time. The responses of these parameters are categorized into three categories, low, moderate and high based on the rules derived using machine learning techniques. Table 1 shows the Indian Weighted Risk Score assigned to each parameter in each category.

TABLE I. INDIAN WEIGHTED RISK SCORE

		IWDRS		
No	**Risk Factor**	**Low**	**Moderate**	**High**
1	Age	10	27	63
2	Family History	16	41	44
3	Personal History	25	36	39
4	BMI	14	39	47
5	Waist Circumference	15	41	44
6	Diet	7	37	56
7	Stress	26	35	38
8	Physical Activity	15	16	69
9	Life Quality	14	22	64

IV. RESEARCH DESIGN

In this study, we validate the IWDRS, with the data which was not used in derivation. Data is collected from Advanced Diabetes Center, Surat, Gujarat (India). 311 adult subjects (age > 18 years), who have been tested for diabetes using the biochemical test in pathology laboratory according to World Health Organization (WHO) guidelines, were selected for this study. Out of total 311 subjects, 180 have tested positive for diabetes. IWDRS is calculated for all 311 subjects. Prediction parameters such as sensitivity and specificity are evaluated along with other performance parameters for an optimal cut-off score for IWDRS. The flow of this research study is as follows:

1) 311 adult subjects' records are used for validation.

2) IWDRS is calculated for each record.

3) Minimum and Maximum value for IWDRS is 142 and 464.

4) Considering 142 as base score, interval 142 – 464 is divided into 10 equidistance cutoffs.

5) Calculate Proportion of population and confusion matrix for each cutoff scores.

6) Calculate Prediction parameters for each cut-off scores.

7) Sensitivity, Specificity, and Accuracy are noted at the Optimal cut-off score.

8) Results are compared with two other Indian DRS.

V. EXPERIMENTS

Data are collected using the same questionnaire which was used to collect data for deriving IWDRS [18]. Data is collected from 311 adult subjects, of both genders, with age more than 18 years. Their diabetes status is confirmed with a biochemical test. 180 out of 311 subjects were diabetic. IWDRS is calculated for each of them.

Minimum and maximum possible score is 142 and 464 respectively. Considering 142 as base score, the IWDRS 142-464, is divided into 10 cutoff scores, which are 142, 175, 207, 239, 271, 303, 336, 368, 400, 432 and 464. Prediction parameters are calculated for the above cut-off score. Results are shown in Table 2.

TABLE II. INDIAN WEIGHTED DIABETIC RISK SCORE: PREDICTION PARAMETERS (MINIMUM AND MAXIMUM POSSIBLE SCORE BEING 142 AND 464, RESPECTIVELY)

IWDRS ≥	**Proportion of Population at High Risk (in %)**	**Prediction**				
		Sensitivity (in %)	**Specificity (in %)**	**PPV (in %)**	**NPV (in %)**	**Accuracy (in %)**
142	100	100	0	57.88	0	57.88
175	99.68	100	0.76	58.06	100	58.2
207	96.46	99.44	7.63	59.67	90.91	60.77
239	90.35	97.78	19.85	62.63	86.67	64.95
271	71.7	90	53.44	72.65	79.55	74.6
287	62.38	86.67	70.99	80.41	79.49	80.06
303	50.16	77.22	87.02	89.1	73.55	81.35
336	33.12	56.11	98.47	98.06	62.02	73.95
368	16.4	27.78	99.24	98.04	50	57.88
400	3.22	5.56	100	100	43.52	45.34
432	0.64	1.11	100	100	42.39	42.77
464	0	0	100	0	42.12	42.12

TABLE III. INDIAN WEIGHTED DIABETIC RISK SCORE: PREDICTION PARAMETERS (MINIMUM AND MAXIMUM POSSIBLE SCORE BEING 271 AND 303, RESPECTIVELY)

IWDRS ≥	Proportion of Population at High Risk (in %)	Prediction				
		Sensitivity (in %)	Specificity (in %)	PPV (in %)	NPV (in %)	Accuracy (in %)
271	71.7	90	53.44	72.65	79.55	74.6
275	70.1	88.33	54.96	72.94	77.42	74.28
278	68.49	87.22	57.25	73.71	76.53	74.6
281	65.92	86.67	62.6	76.1	77.36	76.53
284	63.67	86.67	67.94	78.79	78.76	78.78
287	62.38	86.67	70.99	80.41	79.49	80.06
291	58.2	83.33	76.34	82.87	76.92	80.39
294	54.98	82.22	82.44	86.55	77.14	82.32
297	53.05	82.39	80.39	87.88	72.57	72.99
303	50.16	77.22	87.02	89.1	73.55	81.35

Tables 2 and 3 present the sensitivity and specificity and accuracy of predicting diabetes for different cut-off values for IWDRS. From Tables 2 and 3, the highest prediction accuracy is 82.32% for IWDRS >= 294 and IWDRS >= 300. Sensitivity is 82.22% and 80.56% and specificity is 82.44% and 84.73%, respectively. Though prediction accuracy is same for both cut-off scores, at IWDRS>= 300, sensitivity is less than specificity, meaning that it predicts diabetes negative persons more accurately than diabetes positive persons, while our interest is in identifying diabetes person more accurately. So we choose IWDRS>=294 as the optimal cut-off score.

VI. RESULT ANALYSIS

Our study results are comparable and consistent with other studies reported in scientific literature. Experimental result of validation of IWDRS is shown in Table 3.

Two similar studies are found for Indian population. Mohan et al. [10] have developed simplified Indian Diabetes Risk Score using logistic regression model. Four parameters are used for developing the risk model, namely, 1) Age; 2) Obesity; 3) Physical activity; and 4) History of diabetes in the family. Ramachandran et al. [14] have also developed a DRS for Asian Indian population living in India using a logistic regression model with five parameters. They used 1) BMI; 2) Waist Circumference as a risk factor apart from; 3) Age; 4) Physical activity; and 5) History of diabetes in the family. Initially, Gender and Monthly income were considered as a diabetes risk factor, but not taken into account while developing the model. Table 4 compares the prediction statistics of these two risk score tools with their results with IWDRS.

TABLE IV. COMPARATIVE PREDICTION STATISTICS FOR IDRS, IADRS, AND IWDRS

No.	DRS Tool	Proportion of Population at High Risk (%)	Sensitivity (%)	Specificity (%)	Accuracy (%)
1	IDRS>=10	99.4	100	0.7	10.7
	IWDRS>=175	**99.68**	**100**	**0.76**	**58.2**
2	IDRS>=20	99.0	99.5	1.1	11.1
	IWDRS>=207	**96.46**	**99.44**	**7.63**	**60.77**
3	IDRS>=30	93.3	97.7	7.2	16.7
	IWDRS>=239	**90.35**	**97.78**	**19.85**	**64.95**
4	IDRS>=40	75.9	93.1	25.5	32.4
	IADRS>=13	-	91.8	33.6	-
	IWDRS>=271	**71.7**	**90**	**53.44**	**74.6**
5	IDRS>=50	62.8	84.9	39.4	43.0
	IADRS>17	-	86.4	47	-
	IWDRS>=303	**50.16**	**77.22**	**87.02**	**81.35**
6	IDRS>=60*	42.9	72.5	60.1	61.3
	IADRS>21*	-	76.6	59.9	-
	IWDRS>=294*	**54.98**	**82.22**	**82.44**	**82.32**
7	IDRS>=70	20.9	42.7	81.1	77.2
	IADRS>25	-	54.1	77.4	-
	IWDRS>=368	**16.4**	**27.78**	**99.24**	**57.88**
8	IDRS>=80	6.0	15.1	95.0	86.9
	IADRS>29	-	33.5	88.5	-
	IWDRS>=400	**3.22**	**5.56**	**100**	**45.34**
9	IDRS>=90	0.9	2.3	99.3	89.5
	IWDRS>=432	**0.64**	**1.11**	**100**	**42.77**
	IWDRS>=464	**0**	**0**	**100**	**42.12**

** Optimal cut-off scores. - Data is not disclosed in the reference.*

VII. Conclusion

With prediction accuracy, 82.32%, IWDRS can be proved useful and inexpensive yet effective tool for a two-phase mass screening test for diabetes, especially in developing and underdeveloped countries like India where the undiagnosed or late diagnosis of diabetes is a major problem. In the first phase of the mass screening test, IWDRS can be calculated using an easy to response questionnaire for all subjects. In the second phase, only those subjects, who scored more than optimal cut-off value for IWDRS, are tested for the induced plasma glucose tolerance test using biochemical methods in the pathology laboratory, as per WHO guidelines. This two-phase mass screening approach will reduce the mass screening cost drastically in comparison single phased mass screening using pathology test only. By conducting a pathological test for only 55% of the population, we can detect 82% of the total diabetic person present in the population. In other words, for any given budget for the diabetes mass detection program, we can identify 20% more diabetic person if we use IWDRS tool in the first phase of two-phase diabetes screening.

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Integrated Framework to Study Efficient Spectral Estimation Techniques for Assessing Spectral Efficiency Analysis

Kantipudi MVV Prasad
Research Scholar
Visvesvaraya Technological University
Belgaum, India

Dr. H.N. Suresh
Prof., Dept. of Instrumentation
Bangalore Institute Technology,
Bangalore, India

***Abstract*—The advanced network applications enable software driven spectral analysis of non-stationary signal or processes which precisely involves domain analysis with the purpose of decomposing a complex signal coefficients into simpler forms. However, the proper estimation of power coefficients over frequency components of a random signal leads to provide very useful information required in various fields of study. The complex design constraints associated with conventional parametric models such as Dynamic Average Model, Autoregressive MA, etc. for multidimensional spectral estimation using adaptive filters leads to a situation where higher computational complexities generate significant overhead on the systems. Therefore, the proposed study aims to formulate an efficient framework intended to derive a fast algorithm for processing Adaptive Capon and Phase Estimator (APES). The proposed method is applied to a non-stationary signal which is random. Further, the adaptive estimation of power spectra along with more accurate spectral efficiency has been identified in case of APES. An extensive performance evaluation followed by a comparative analysis has been performed by obtaining the values from different spectral estimation techniques, such as APES, PSC, ASC, and CAPON. Moreover, the framework ensures that unlike others, APES is subjected to attain superior signal quality regarding Power Spectral Density (PSD) and Signal to Noise Ratio (SNR) while achieving very less amount of Mean Square Error (MSE). It also exhibits comparatively low convergence speed and computational complexity as compared to its legacy versions.**

***Keywords*—Amplitude and phase estimation; ASC; capon spectral estimator; spectral estimation; PSC**

I. Introduction

Spectral analysis of signals is the measurement of power spectral components further analyzed to investigate the frequency coefficients of a random signal. The power distribution over a non-stationary signal eases the computation of frequency components.

However, the large scope of its applicability extended into various fields of study for software-driven electronic devices including Speech Analysis, Medicine, RADAR, and SONAR communications, etc. The prime reason lies in the fact that the frequency content of an observed signal can provide very useful information in the fields like multidimensional intelligence Naval and military communications [1], [2]. A data independent method namely Periodogram was initially developed by the author named Arthur Schuster with the purpose of estimating spectral coefficients of a non-stationary signal efficiently. The numerical computing method which is applied to a synthetic signal has adopted the concept of Fourier transform followed by efficient utilization of FFT algorithm [3]. However, the algorithm is claimed to have a limited scope of applications due to various factors such as poor resolution and high side lobe problems. This situation further leads to a scenario, where retrieval of significant information by analyzing signal coefficients becomes entirely unfeasible.

An in-depth investigational study gives an insight into the fact that the conventional data-dependent (adaptive) methods for both non-parametric and parametric approaches attain superior performance efficiency in comparison with the conventional data independent methods like Periodogram. Adaptive data dependent methodologies are also claimed to achieve optimal computational cost. The applicability of data-adaptive approaches further leads to improve the spectrum quality of a signal significantly and helps to retrieve more information under study. Therefore, it has gained the interest among more researchers to explore its applicability towards mitigating issues of spectral estimation. These advantages have led to increasing interest in data-adaptive approaches towards the problem of spectral estimation. The proposed study thereby formulated a novel framework to access the performance efficiency of the conventional APES technique and determine the quality signal concerning PSD and computational complexity perspectives [4]. The study also gives insight into the in-depth performance analysis of conventional PSC, ASC and Capon estimation methods while improving the SNR as well as reducing the MSE of a non-stationary process. The experimental outcomes precisely exhibit the performance efficiency of the APES method on evaluating spectral correlation (SC) and effective spectral growth regarding SNR and PSD [5]. The paper is organized in a way where Section II discusses the essentials of the spectrum estimation followed by existing survey highlighted in Section III. However, Section IV discusses the conceptual framework for APES spectrum estimation. Finally, Section V discusses the outcomes of the study followed by Section VI that discusses conclusion and future work.

II. Background

Most phenomena of signals that occur in nature or practice are typically random and are best modeled as random signals. However, examples of such random signals include various non-deterministic processes, but they are not limited to speech/audio signals and thermal noise generated by electronic devices. Due to the random fluctuation of these signals, they are best characterized regarding statistical averages. The autocorrelation function of a random process is a statistical average used for characterizing these random signals in the time field. A closer look into the estimated PSD spectrum shows that how frequency contents are distributed over periodic time. The spectral estimation thereby involves a process to approximate the uniform distribution of frequency components of an arbitrary signal. The process of estimating the power distribution over frequency components of a non-stationary process thereby exhibits the power band of a signal.

Power spectral estimation has applications in many fields. Speech signals which are periodic are analyzed using the spectrogram. In case of frequency domain analysis provides useful information that can lead to speech recognition and generation. In the sensing fields of RADAR and SONAR, the spectral content of received signals may provide information about the targets of interest in a given scene of interest (see Fig. 1). Also, the power spectrum of signals may provide information about radio frequency interference in such a signal and hence lead to effective suppression of the interference. In MEDICINE field, power band of EEG signals can be used to evaluate the different sleep cycles in humans [6]. These can/are used to investigate and study narcoleptic (a disease characterized by the inability to properly regulate sleep-wake cycles) patients. More recently these are used in audio.

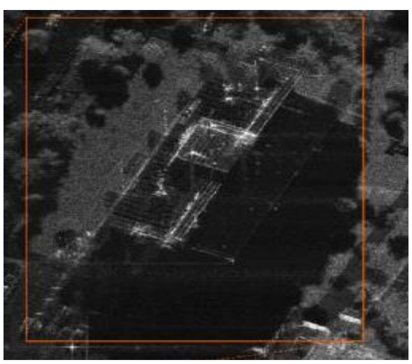

Fig. 1. Synthetic aperture radar imaging.

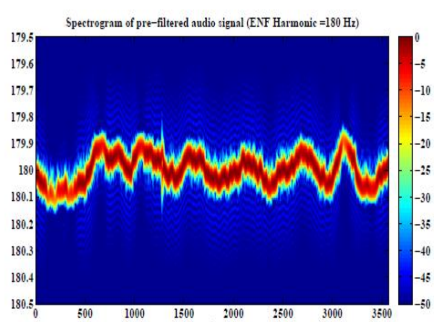

Fig. 2. Spectrogram.

The spectrogram of the audio signal can indicate the presence of the electric network frequency (see Fig. 2), which can be used for digital audio authentication. Synthetic aperture radar imaging: (A) Photograph of the object at 45 degrees (B) SAR image formed using Spectral Estimation (FFT) (Fig. 1.).

There are two broad approaches to manage spectral coefficient estimation. The principal approach is known as the non-parametric technique, and the other is known as the parametric strategy. However, the non-parametric techniques expect no earlier data about the information, while the parametric strategies accept a particular model of the information, which then outcomes in an issue of parameter estimation. The parametric strategies are more exact than the traditional non-parametric systems when the expected model is precise. Notwithstanding, they perform inadequately when there are errors in the information modeling.

A. *Problem Formulation*

Let $\left\{Zn,\vec{n},\ n=0,1,\ldots,N-1,\vec{n}=0,1,\ldots,\vec{N}-1\right\}$

Denote a 2-D discrete-time data sequence. For a frequency pair (ω,ϖ) of interest, we model $Zn,\vec{n}$ as:

$$Zn,\vec{n}=\alpha(\omega,\varpi)ej(nw+nw)+w_{n,\vec{n}}(\omega,\varpi),$$

$$n=0,1,\ldots,N-1,\ \vec{n}=0,1,\ldots,\vec{N}-1 \tag{1}$$

Where, $\alpha(\omega,\varpi)$ denotes the complex amplitude of a 2-D sinusoid with frequency (ω,ϖ) and $wn,\vec{n}(\omega,\varpi)$ denotes the unmodeled noise and interference at the frequency (ω,ϖ). The problem of interest is to obtain the estimate of $\alpha(\omega,\varpi)$ from the 2-D data sequence for all (ω,ϖ) of interest. In 2-D SAR imaging applications, for example, $\alpha(\omega,\varpi)$ would be proportional to the radar cross-section of a target scatterer located at a range proportional to ω and cross-range proportional to ϖ .

B. *Energy Spectral Density*

Consider a signal $x[\eta]$ (discrete) with finite energy, that is,

$$E=\sum_{n=-\infty}^{\infty}|\,x[\eta]\,|^2<\infty \tag{2}$$

Then its discrete-time Fourier transforms (DTFT) exists and is given by:

$$X(\omega)=\sum_{n=-\infty}^{\infty}|\,x[\eta]e^{-jwn} \tag{3}$$

Where, ω is the angular frequency variable measured in radians per sample? From Parseval's theorem equation (1-1) can be written as:

$$E = \sum_{n=-\infty}^{\infty} |x[\eta]|^2 = \frac{1}{2\pi}\int_{-\pi}^{\pi} |X(\omega)|^2 \quad (4)$$

From the equation above the energy spectral density of $x[\eta]$ which is the distribution of the energy of the signal of frequency is therefore defined as:

$$S_{xx}(\omega) = |X(\omega)|^2 \quad (5)$$

Note that the ESD $S_{xx}(\omega)$ can be written as the computation of Fourier transform associative autocorrelation sequence $\Gamma_{xx}(k)$ of the signal

$$x[\eta]: \; S_{xx}(\omega) = \sum_{n=-\infty}^{\infty} \Gamma_{xx}(k) e^{-jwk} dw \quad (6)$$

Where,

$$\Gamma_{xx}(k) = \sum_{n=-\infty}^{\infty} x^*[\eta] x[n-k] \quad (7)$$

The analysis above is expressly for signals with finite energy (deterministic signals). However, signals typically encountered in applications are characterized as stochastic processes and do not have finite energy and hence do not possess a Fourier transform. These random signals, however, possess and average power can be described by their PSD.

C. Power Spectral Density

Consider a stationary stochastic process $y[\eta]$, where $E\{y[\eta]\} = 0$ for all η. The auto covariance function (same as Auto Correlation function for stationary stochastic process with mean zero) of $y[\eta]$ is given by

$$\Gamma_{yy}(k) = E\{y^*[\eta] y[\eta - k]\} \quad (8)$$

Where, $E\{\bullet\}$ is the statistical average over all realizations? The PSD of $y[\eta]$ is well-defined as:

$$\theta_{yy}(\omega) = \sum_{n=-\infty}^{\infty} \tau_{yy}(k) e^{-jwk} \quad (9)$$

This simply the Fourier transforms of the AC function. Note that the inverse transform of this PSD gives $\tau_{yy}(k)$ as shown below:

$$\frac{1}{2\Pi}\int_{-\pi}^{\pi} \theta_{yy}(\omega) e^{jwk} dw = \sum_{s=-\infty}^{\infty} \tau_{yy}(s)\left[\frac{1}{2\pi}\int_{-\pi}^{\pi} e^{jw(k-s)} d\omega\right] = \sum_{s=-\infty}^{\infty} \tau_{yy}(s)\delta_{ks} = \tau_{yy}(k)$$

Where, δ denotes the Kronecker delta function. Note that the average power of the stochastic process $y[\eta]$ is given by the zero lag o the AC function $\tau_{yy}(0)$:

$$E\{y[\eta]^2\} = \tau_{yy}(0) = \frac{1}{2\pi}\int_{-\pi}^{\pi} \phi_{yy}(\omega) d\omega \quad (10)$$

This equation (1-9) leads to the motivation for defining the PSD in (1-8). The PSD can also be defined as:

$$\phi_{yy}(\omega) = \lim_{N->\infty} E\left\{\frac{1}{N}\left|\sum_{\eta=1}^{N} y[\eta] e^{-jwn}\right|^2\right\} \quad 11)$$

Which is equivalent to the definition in (1-8) under the assumption that the autocovariance sequence (ACS) $\tau_{yy}(k)$ decays quickly.

III. Existing Survey

Guo *et al.* [7] investigated the outcome of frequency shifting in an acoustic feedback control system. This work recommends a solution to achieve an unbiased approximation by eliminating the slowly time variable part in adaptive filter estimation.

Kim *et al.* [8] suggested a less computational improved time-based and spectral constraints approximation methods for SIFT output of radar signals. This method enhanced the spectral resolution of a received radar signal by utilizing the STFT outputs. Similarly, it will also improve the time-based resolution of the complete system for obtained radar signals. The performance of the executed approaches are hypothetically examined, and it accomplishes the low computational complexity is obtained.

Rosado *et al.* [9] analyzed the presentation of an adaptive multilayer technique for decreasing the coherent noise associated with spectral of ultrasound echoes. The proposed strategy effectively lessened predisposition and coherent noise related to standards for different methodologies, demonstrating its favorable position for spectral investigation of muddled back-scattered signals.

Fu *et al.* [10] introduced a novel technique for adaptively investigating the time-varying AC of non-stationary signals. This article also gives the information about its applications to time-frequency spectrum analysis. This method implements a local valuation with sliding window method to have a certain bandwidth to investigate time-varying AC locally.

Zhang *et al.* [11] proposed a novel adaptive Kalman filter based recursive technique to estimate the spectrum for measuring time-varying non-stationary signals. The measurements in Kalman filter are decided adaptively as indicated by the state divisions. The simulation results show that the proposed method achieves a better time-frequency resolution that compared to the traditional spectrum estimations.

Cheng *et al*. [12] presented an alteration of traditional least mean squared error (MMSE) inappropriate subtraction calculation by acquainting a versatile averaging variable with precisely evaluate the from the earlier SNR. Execution of the adjusted process concerning the earlier SNR is assessed by contrasting and ordinary phantom subtraction calculation. Enhanced results are gotten as far as discourse quality measures for different sorts of commotion when the time-recurrence fluctuating averaging element, proposed in this paper; the customary subtraction rules are also exhibited.

Bracale *et al*. [13] concentrated on otherworldly parts of force static converters utilized for both train drives, and assistant administrations can be exceedingly time-changing with ensuing troubles in their location. In this paper, a versatile asymmetric strategy is proposed to ascertain time-changing phantom segments with great precision and adequate computational endeavors. The strategy depends on a versatile system which minimizes the mean square relative blunder of sign estimation. The utilization of the strategy to an assistant static converter demonstrates its high precision and satisfactory computational endeavors.

Alty *et al*. [14] displayed a computationally effective sliding window time redesigning of the Capon and sufficiency, and stage estimation (APES) coordinated channel bank otherworldly estimators in light of the time-variation relocation structure of the information covariance network. The exhibited calculation shapes a characteristic expansion of the most computationally effective calculation to date and offers a critical computational addition when contrasted with the computational unpredictability connected with the bunch re-assessment of the appraisals for every time-upgrade. Moreover, through recreations, the calculation is observed to be numerically better than the time-overhauled precise gauge framed from straightforwardly redesigning the information covariance grid.

The study of Huillery *et al.* [15] concentrated on an instance of a spectrogram built from a limited length discrete-time boisterous sign is introduced. This study expands past takes a shot at negligible insights on two viewpoints: to start with, the most extreme probability appraisal of the commotion is detailed by clear investigation of the likelihood conveyance of the time-recurrence coefficients. Second, the decision of an ideal insignificant subset is examined. The sign versus commotion segregation property of the ghastly kurtosis is utilized to choose a negligible subset which guarantees a reasonable exchange off between the predisposition and the difference of the estimator. The subsequent exhibitions are talked about and contrasted and those of different strategies through numerical recreations on engineered signals. The utilization of the MiniSMaL estimator in a period recurrence recognition method is at last shown on a certifiable sign.

The study of Zhang *et al.* [16] proposed another versatile Kalman channel based recursive range estimator for measuring a time-differing range of non-stationary signs. The non-stationary sign is demonstrated as a period shifting autoregressive process, and the time-differing parameters are portrayed by smoothness prior's model. Another Kalman channel calculation with a variable number of estimations is utilized to recursively figure out the TVAR coefficients and after that, the time-differing range is formulated. The quantity of estimations in the Kalman channel is resolved adaptively as per the state gauge subsidiaries. Moreover, a quick QR disintegration calculation is created to decrease the math unpredictability of the proposed KFVNM calculation. Reenactment results demonstrate the proposed Kalman channel based recursive range estimator can accomplish a superior time-recurrence determination than the customary parametric range estimations. Its potential application to power quality checking is likewise shown.

Glentis *et al.* [17] proposed quick calculations for versatile Capon and adequacy and stage estimation (APES) techniques for efficient examination of time fluctuating signs. A quick, steady, and non-recursive formulae are inferred considering of time moving properties of the related variables. As a result, productive recurrence space recursive slightest squares (RLS) based, and also quick RLS based calculations for the versatile estimation of the force spectra are created. Soundness issues of the recurrence area estimators are considered, and adjustment techniques are proposed. The computational intricacy of the proposed calculations is lower than applicable existing strategies. The execution of the proposed calculations is exhibited through broad reenactments.

The study of Resende *et al*. [18] introduced a structure that offers ascend to unearthly gauges that speak to the genuine basic range with preferred devotion over routine LS strategies by permitting a subjective exchange off between differences of phantom gauges and following capacity of the estimator along with the recurrence area. The straight forecast mistake is deteriorated through a force correlative channel bank, and segments of every band are broke down by various window lengths, permitting long windows to track gradually differing signs and short windows to watch firstly shifting parts. The connection network of the info sign is appeared to fulfill both time-upgrade and request overhaul properties for rectangular windowing capacities, and an RLS calculation given every property is displayed. Additionally, reenactments looking at the execution of customary and the proposed multi-band LS strategies are delineated and examined.

IV. Conceptual Framework

The proposed study aims to formulate a Numerical computing framework for estimating spectrum components of a synthetic signal using Capon, PSC, APES and ASC techniques. The study intended to perform spectral estimations by reducing the (MSE) of APES linear regression models. The proposed system aims to design a novel framework is integrated with different significant spectral estimation frameworks, e.g., Capon, PSC, APES, and ASC to perform spectral estimation on non-stationary signals by reducing the (MSE) of all linear regression models. It also performs a comparative analysis in between the conventional state of art spectral estimation processes to compute bit error rate (BER) concerning SNR. Moreover, the proposed model also applies a linear shrinkage based approach (includes both Capon and APES Spectral Estimators) to intensify the spectral quality of an input signal. This section of the study discusses the conceptual model intended to carry out spectral estimation of an input sinusoidal signal by applying four different spectral estimation methodologies such as PSC, ASC, CAPON, and APES. It also highlights a comparative analysis to ensure the effectiveness of the proposed integrated framework for APES estimation concerning reducing MSE and enhancing the signal quality.

To understand the error pattern with the performance metric (MSE), the filter length (FL) and signal to SNR measurement are required for the given signal input.

Spectral analysis associated with signal components especially for random signals provides necessary information about the frequency and power components (PSD). The obtained values can be further utilized for numerical integration, analytical modeling, prediction and filtering of the deserved random signal. The prime objective of the spectral estimation process is to formulate a correlation between the spectral components to estimate the spectral density of a random signal concerning different time sample sequence. It deals with the computation of frequency components to determine the significant spectrum component of a random signal.

The following Fig. 3 depicts a pictorial representation of the proposed system shows how the experimental process has been carried out by evaluating the different set of operations during the computation process. It includes generation of the sinusoidal signal, which is further interpreted for the computation of PSD. The model performs Monte-Carlo simulation to perform numerical integration on PSC, CAPON, APES, and ASC. Finally, the proposed system SC Density of the input signals by applying the four algorithms and compute the MSE. SNR, MSE and filter length (M) are considered as the performance parameters, respectively. The MSE value has been computed using a function, which considers the filter length as input parameters.

Fig. 4 represents a flow diagram of the proposed model where a different set of operations such as SAR processing, spectral equalization, and signal chipping are performed. Signal chipping is used to segregate a set frequency components for better resolution of computation. The framework also considers 2-D DFT and re-sampling for construction of signal with better resolution.

After performing 2D DFT different spectral estimation techniques are evaluated to generate the consecutive spectrum (i.e., PSD and PSC). A component called as signal mosaicking is applied on the retrieved signal for re-shaping. The following is the algorithm designed and implemented in a numerical computing framework to evaluate the performance efficiency of the APES method.

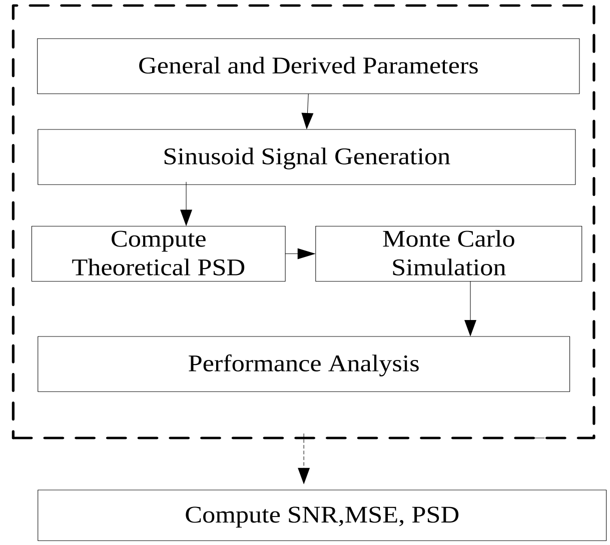

Fig. 3. System architecture of the proposed method.

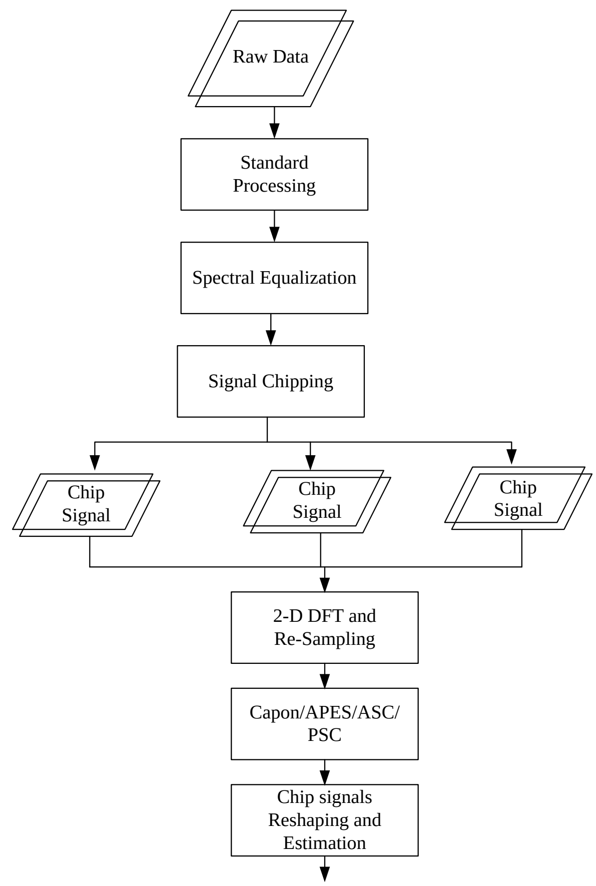

Fig. 4. Flowchart of the proposed method.

Mathematical Algorithm Design: An Adaptive Framework for Spectral Estimation

Input: N (Number of Samples), f_s (Sampling Frequency), M (Filter Length), A (SNR)
Output: Performance Evaluation of Spectral Estimation Techniques on non-stationary signals. (*Capon, ASC, APES, PSC*)
PROCEDURE:
START

1. Input Number of samples ← N
2. Input sampling frequency ← f_s
3. Input Sample SNR ← snr
4. Input Filter Length ← M
5. Generated signal SNR, matrix A(1×2) ← [1,1]
6. Generated signal Frequency, matrix f(1×2) ← [0.3,0.2]
7. trails = 10
8. Sampling period, Ts ← 1/fs
9. nT (1×N) ← Ts
10. Generated signal Y ← A*sin(2*pi*f*nT)
11. h ← PSD (Y)
12. Initiate **Monte-Carlo Simulation**
13. FOR trails (1: trails)
    a. Signal xin ← Y+Gaussian Noise
    b. Function **SCD**
    c. Pass In: xin,M,METHOD,fs,res
    d. Pass Out: SCD F A
    e. Function **PSC**
    f. Pass In: Y, M
    g. Pass Out: cross PSD, wave no (k)
    h. Function **ASC**
    i. Pass In: Y, M
    j. Pass Out: cross PSD, wave no (k)
    k. Function **CAPON**
    l. Pass In: Y, M
    m. Pass Out: cross PSD, wave no (k)
    n. Function **APES**
    o. Pass In: Y, M
    p. Pass Out: cross PSD, wave no (k)
14. END (trails)
15. Plot power spectral distribution, **SCD**
16. calculate MSE
17. performance parameters.

END

The above algorithm depicts the procedures to compute the performance estimation of different spectral estimation techniques. This method gives the more accurate value of spectral estimates but, the lower resolution than the schemes they based on. A comparative analysis has been performed in between the entire standard APES algorithm and the conventional methods which show that integrated APES outperforms the conventional shrinkage based techniques regarding detection of every frequency and also the amplitude of spectral components. Fig. 3 shows the system design architecture of the proposed method. It contains as an input like general and derived parameters like N, M, A, SNR, f. fs, t, ts, etc. The sinusoidal signal is generated after collecting all the inputs to the system. Then, the next step is to calculate the PSD of the given input signal. Apply Monte Carlo method to simulate the signal. Then add the Gaussian noise to the input signal. Perform the PSC, CAPON, APES and PSC techniques to simulate the experiments. Finally, calculate the SC for the above-mentioned techniques. Estimate the MSE and filter length of the signal. Analyze the given signal using performance parameters like MSE, SNR, and filter length. Fig. 4 shows the flowchart of the proposed method. It gives an explicit conceptual aspect of the proposed framework.

V. Results and Discussion

The computational efficiency offered by the proposed method is illustrated in Fig. 4, where the process involves effective SC of APES method is illustrated as well as the spectral estimation of the above algorithm is shown as a function of the sliding window data size N. here the number of observed samples N=100, filter length M=8, sampling frequency fs=1, SNR=35 is assumed for the implementation purposes. Fig. 5 to 19 shows the result obtained after simulating this proposed framework on a numerical computing tool. It shows that it gives a better spectral estimation for a given non-stationary signals.

Fig. 18 and 19 depicts that APES significantly achieves better outcomes concerning MSE and SNR thus exhibits the conventional spectral estimation techniques.

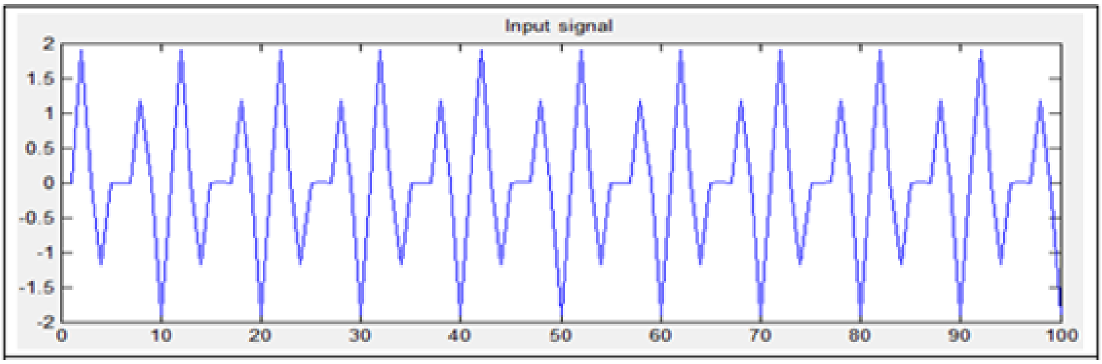

Fig. 5. Input signal.

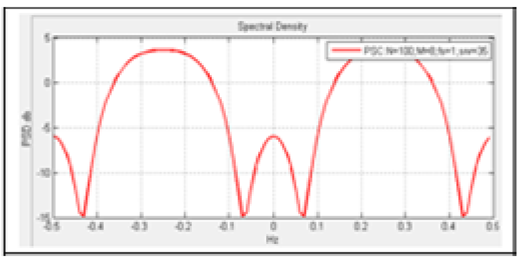

Fig. 6. PSC spectrum estimation.

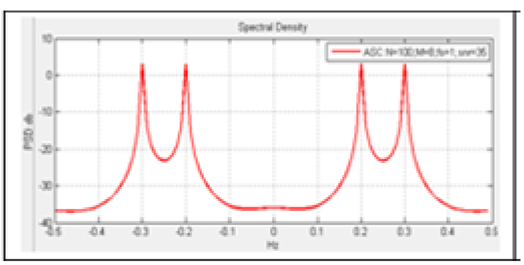

Fig. 7. ASC spectrum estimation.

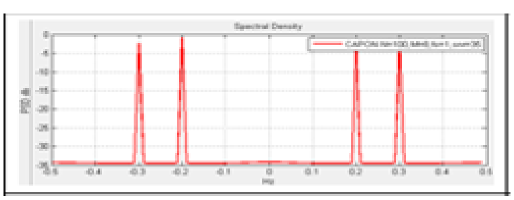

Fig. 8. CAPON spectrum estimation.

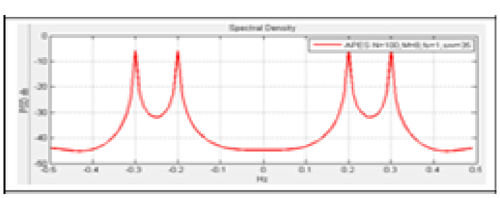

Fig. 9. APES spectrum estimation.

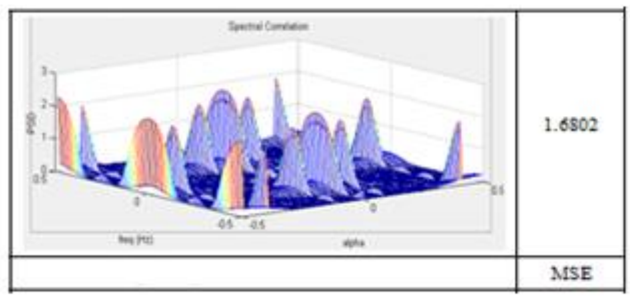

Fig. 10. Spectral correlation for PSC.

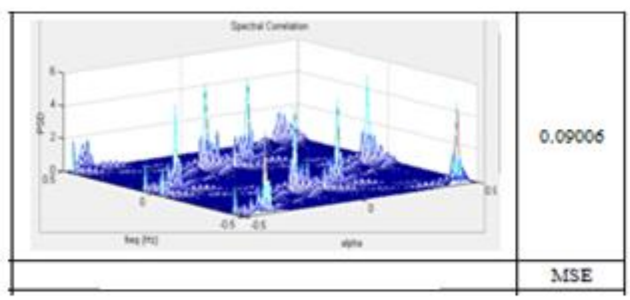

Fig. 11. Spectral correlation for ASC.

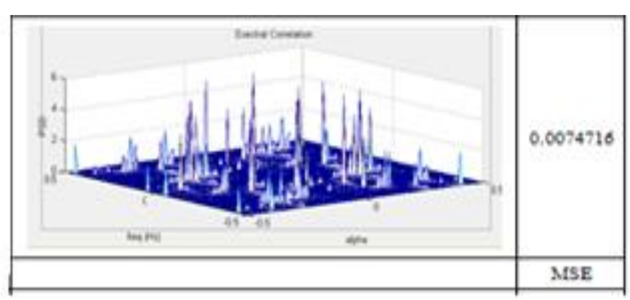

Fig. 12. Spectral correlation for CAPON.

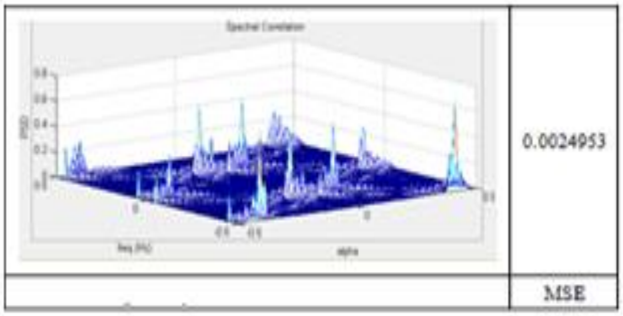

Fig. 13. Spectral correlation for APES.

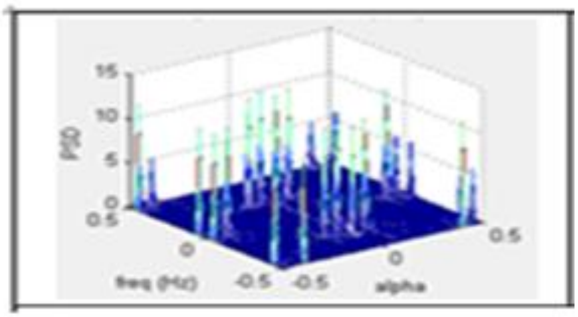

Fig. 14. Spectrum correlation (PSC).

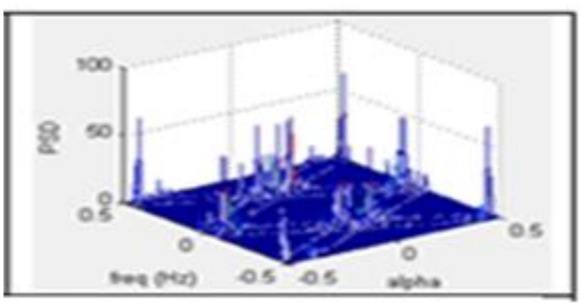

Fig. 15. Spectrum correlation (ASC).

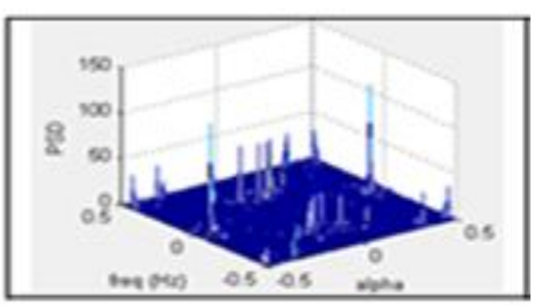

Fig. 16. Spectrum correlation (CAPON).

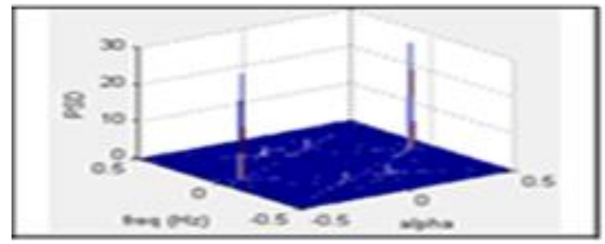

Fig. 17. Spectrum correlation (APES).

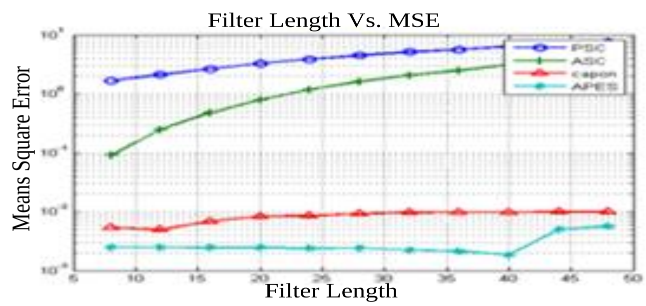

Fig. 18. Filter Length vs. MSE comparison for PSC, ASC, CAPON and APES.

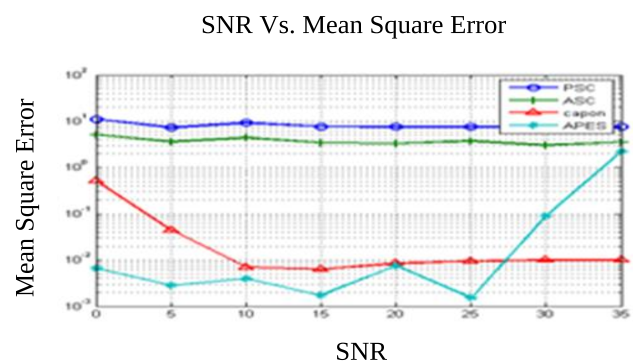

Fig. 19. SNR vs. MSE comparison for PSC, ASC, CAPON and APES.

VI. Conclusion and Future Work

The present paper has studied about the effectiveness of existing compressive sensing algorithms that has been seen too.

Further, the study introduced the shrinkage-based APES spectral estimators, termed integrated linear regression framework for APES, by minimizing the MSE of APES in a linear regression shrinkage approach.

Regarding resolution, the proposed framework for APES is found to be a superior method. It has the appealing property that this resolution, even for fairly high target densities, improves as the SNR increases. For applications in which target discrimination is critical, it may be the preferred choice. In particular, in a polarimetric case, APES may be able to discriminate close targets with different polar metric signature where Capon or a traditional matched filter approach cannot. The asymptotic analysis of the proposed APES shows that it significantly reduces the computational overhead and obtains efficient convergence speed like RLS. Therefore a closer look at the above Fig. 18 and 19 exhibits that to a large extent the proposed framework for APES achieves very less MSE as compared to the conventional spectral estimation techniques. Future work will focus on testing and apply integrated APES to In SAR, DInSAR, and PolDInSAR. Using large data sets in DInSAR should allow a real-life evaluation of the phase quality of both algorithms. Also, DInSAR in urban areas, where side lobe mitigation is a real issue, and large sets of SLCs are available, can be expected to benefit directly from these algorithms. Another possible research direction is to find criteria and algorithms to automatically select some of the processing parameters.

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