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The Effectiveness of Using Mobile Learning Techniques to Improve Learning Outcomes in Higher Education

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Abstract—Recently Mobile technology is considered an effective way to improve students' skills such as positive thinking, collaborative, communication, as well as it is considered the main part of major innovation in many e-learning research areas. As a result of the 21st. century requirements, skills were developed to address the rising needs in higher education which causes a shifting paradigm from the traditional methods of teaching to M-learning. In this research, we discuss the effect of using Mobile learning techniques to improve learning outcomes in Higher Education. We have implemented a web-based survey through two questionnaires. The questionnaires were distributed among 200 students in the second and third levels in the computer science department at both Community College and College of Arts and Science. This research explores a study on e-learning using mobile technology to identify students' perceptions in the acceptance of mobile techniques and recognize the quality of mobile services for academic and social purposes to improve teaching strategy and learning performance in higher educational organizations. The outcomes of this research would support the evolution of M-learning at the university-level and cause shifting the traditional learning methods by merging M-learning methodologies as a learning management system that provides mobile learning services to students and teachers any time and from any location. The research study shows some important results towards the integration of mobile technology into teaching include: student positive perception, facilitates student concentrate, flexible access to m-services for learning materials, and increases students' skills in using mobile technology for e-learning.

Keywords—E-learning, M-learning, learning outcomes, teaching tools, Higher Education

1 Introduction

Originally the educational environment begins with traditional learning, where students are required to attend the classes. The other way round, distance learning was

used where students could use videos and books to study abroad. Later the computer embedded in the educational strategy, the learning materials were presented through computers which are called online learning [1]. In 21st century information and communication technology have become an essential section of the teaching process by changing all aspects of education to improve a lecturer's pedagogical practices and promote effective ways to manage time in the classroom [2]. In the late 80s, E-learning emerged as a new way of technologies in modern education and training systems.

The recent learning management systems (LMS) environment of E-learning that accessed using wireless devices (such as, mobile phones, smart mobile phones, Apple's iPods, or tablet PCs, etc.) is called M-learning. The applications of these devices are integrated with the Wi-Fi, 4G, and 5G telecommunication networks which are mainly based on wireless technologies usage which allows students to access learning resources include lectures, assignments, quizzes and collaborate or support activities in fieldwork without any restrictions on time and location. [3, 4]. Mobile devices help students to co-operate with their peers in programs, social media for email, online messaging, blogging, and various social networking sites, that allowing students to progress their programs by gaining credits [5, 6]. M-learning, as a new model, promotes elasticity; for which students don't need to be in a specific age or having specific skills to participate in learning approaches [7]. The main objectives of this research include, (1) identifying students' perceptions in the acceptance of mobile techniques and recognize the quality of mobile services for academic and social purposes to improve learning in higher educational institutions, (2) determining students' level skills in technological literacy [8].

This paper is organized as follows: Section 2 represents the literature review of the effect of M-learning and the sharing of knowledge between students in higher education institutions (HEIs). Section 3 introduces some comparisons between the E-learning and M-learning. Section 4 illustrates the M-services and teaching tools in HEIs. Section 5 introduces a quantitative research methodology for detecting the students' feedback on the acceptance of mobile technology and evaluate the quality of mobile services for academic and social purposes, as well as for determining the students' level skill in technological literacy. Section 6 presents the results and discussion. The paper is concluded in Section 7.

2 Related Work

Sharples, (2000) [9] suggested a scheme for M-learning through the incorporation of hardware, software and mobile technology into the learning process to improve the interaction between students and their teachers by increasing the physical distance between them, since M-learning is a technology of any time anywhere. Furthermore, Park (2011) [10] indicated that M-learning is capable of improving traditional learning through effective applications that facilitate interaction in a formal learning environment to allow interactive learning resources in a conducive virtual environment for life-

long learning. Chen et al. (2008) [11] pointed out the importance of studying the perceptions of students and their requirements for using M-learning to help the decision-maker adoption of mobile learning successfully in the university-level environment.

Kothamasu (2010) [12] presented that mobile learning is not just learning through wireless devices, but mobile phones can provision several emergence services such as SMS, MMS, Email, etc. The authors show that, in addition to mobile communications, available. Alzaza and Yaakub, (2011) [13] explore the importance of using M-learning services for university-level students in Malaysia. The outcomes demonstrated that the course enrollment and exam results are the greatest services' rate followed by library, schedule, and admission services. Research by Adeyeye et al. (2013) [14] presented that there are many factors affect the success or fails of mobile learning-based projects. These factors are based on software accessibility, institutional support, network connectivity, study curriculum capability, student experiences, and the technology owned by the students. According to Behera (2013) [15] and Sa´nchez-Prieto et al. (2016) [16], M-learning is included in E-learning, but it is a separate approach, as M-learning performance can be implemented based on understanding the challenges and opportunities of mobile devices. Mohanna (2015) [17] presented the possibility of integration among M-learning, software and hardware technologies to create multimedia applications capable of facilitating the interaction of educational content in various formats such as lectures, quizzes, tutorials, games, short messages, and multimedia. As an attempt to explore the use of M-learning in universities, Andrew and others (2017) [18] addressed classes of ways, including promoting on-campus interactivity through mobile devices, a student needs an inquiry, and low-cost M-learning approaches. Deemah A. Al-Arabiat, (2018) [19] examines the effect of M-learning and the sharing of knowledge between students at the university level. The outcome of the research presented that, mobile learning technical barriers have a negative effect on M-learning and the growth of cloud computing will expand incentives to address M-learning's technical problems.

3 E-learning and M-learning

E-learning includes the use of computers, wireless devices, and video conferences through the internet, not only for content delivery but also for interaction among students. M-learning is considered as an extended generation of E-learning supported by wireless devices [20]. The main feature and benefit of M-learning are that it isn't limited to a specific place, such as sitting in a classroom or in front of a computer. Students can use M-learning anywhere and anytime as well as teachers, can provide students with materials and resources anywhere anytime they want (see Figure 1). This concept gives the learner the new freedom for learning, it also increases the flexibility of teachers, who can develop (on-the-spot) learning materials to meet specific needs or provide direct feedback and support to students. The M-learning concept can be classified into three main classes include *mobility of learning*, *mobility of the learner*, and *mobility of technology* as shown in Table I [21].

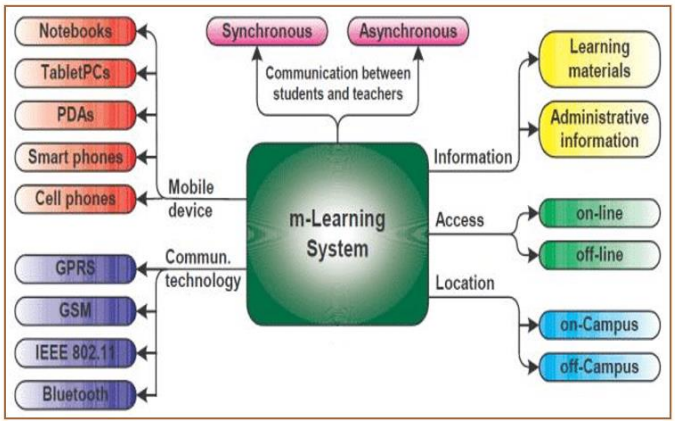

Fig. 1. M-learning system classification

Table 1. M-learning classification and features

M-Learning Classes	Features
Mobility of technology	The ability to use portable digital devices to deliver educational materials to all participants based on wireless application protocols (WAP) and wireless fidelity (Wi-Fi). Also, they have many services such as Email, SMS, MMS, etc.
Mobility of Learner	The ability to learn and communicate with other learners everywhere and anytime through a specific delivery channel.
Mobility of Learning	The ability to transmit all different educational materials of higher educational learning via mobile phones.

3.1 Comparison between E-learning and M-learning

Both E-learning and M-learning models have some differences among them as shown in Table II and have common features between them as follows [22]:

1. The two models are student centered, teaching, learning process (i.e., self-learning).
2. Students can access and explore the Internet by electronic devices such as computers, mobiles, PDA, etc.
3. Provide interaction between participants in the educational process: students, tutors, and institutions.
4. Provide learning opportunities for many students.
5. Deliver educational materials in different ways such as texts, images, and video clips.
6. Enable automatic attendance for a student without entering the classroom actually.
7. The two models include infrastructure and a broad community-based approach to wired and wireless devices technologies.

Table 2. Comparison between some feature of E-learning and M-learning

Feature	E-Learning	M-Learning
Devices	PCs, laptops	Smart Phone, PDA and Tablet
Structure	Structured, formal and time-bound format of teaching.	Unstructured, on-demand, timely and context-aware form of education dissemination.
Network	Wired and Bandwidth	Wireless, GPRS, Bluetooth, 4G, and 4GLET
Protocol	Web-Based	WAP-Based
Accessibility	Private location	No geographical location
Connectivity	Intranet or Internet	Mobile Networks, GSM, GPRS, UMTS, and CDMA.
Communication protection	low levels of protection because of using multiple devices	More protection because of using personal devices
Instructor to Student communication	Asynchronous Delayed (E-mail) Interactive	Synchronous Instant message & MMS Spontaneous
Usability	Difficult to transfer books and files between individuals.	easy to exchange books and files between learners by Bluetooth and IR technologies
Learning process	Simulated Situation	Social Interaction

4 M-services and Teaching Tools in Higher Education

With the exponential growth of technology particularly in both mobile devices and wireless networks. The main objective of Higher Education Institutions (HEIs) attempt to improve learning outcomes and enhance the academic performance of the students by integrating students with M-learning. So, HEIs are allowing M-learning services based on different teaching technological tools to develop their services. Among these tools Social networks, Web-based platforms, internet of things (IoT) [23].

4.1 M-learning services

In this paper, we have classified M-learning services into two categories based on learning materials and administrative information services [24]:

Learning materials services: These services based on the contents of student courses that allow students to:

- Access to course material
- Access continuously the course content and online presentation
- The ability to access the coursework tools (assignments, quizzes, announcements, timetables, user management, and etc.)

Administrative services: Administrative information services of M-learning allow students to [24]:

- Automatic evaluation of teaching system.
- Provide the opportunity of taking external and internal exams.
- Admission services and course registrations.
- Automated library services

- Provide a discussion of new ideas and suggestions for addressing teaching and research issues.
- Encourage comprehensive learning delivery.
- The achievement of all learning phases and control the students learning outcomes.
- Create a universal educational and research environment, etc.

4.2 Educational tools based on M-devices

Teaching tools based on mobile technologies include Social networks, Web-based platforms, and the Internet of Things (IoT), that support activities of teachers to introduce advanced and effective ways of learning [25].

4.3 Social network tools

Social networks allow academic staff to share knowledge among students. Also, enables them to interact with other teachers at other locations to get different perspectives on learning, and teaching [45, 46]. Social network tools for teaching are introduced in Table III, these tools enable students to collaborate in learning and improve their skills, and collaboration. As a result, social networks develop students' performance and motivation for learning [26].

4.4 Web-based platforms

Table III presented some web-based platforms that support teachers in their teaching activities to mentor the students and adoptive a comprehensive learning process with many attractive courses [27].

Table 3. Teaching Tools Based on Mobile Technologies

Educational technology tools	Type	Tools	Benefits
Learning tool	Mobile devices	mobile phone, PDA, smart phone, (Apple's iPod), or tablet	1- Facilitate of innovative learning activities. 2- support the process of knowledge acquisition 3- Develop communication, problem-solving, creativity and a variety of high-level skills in students. 4- Enhance the student's motivation to learn .
Teaching tools	Social networks	Facebook	1- engage students in learning and helps them develop skills in creativity, collaboration and communication
		Twitter	2-improve students' performance, motivation for learning.
		Blogs	3- Blogs are used for collaborative learning. students can publish their course projects and assignments and also explore the work of others.
		YouTube EDU	4- YouTube EDU, it offers educational videos developed by diverse institutions. Teachers are able to adapt these videos to their particular needs
	Web-based platforms	Rapid Cycle Evaluation Coach	1- Depending on the platform, these tools can support effectively the new role of professors as mentors of students.
		TED-Ed	2- Teachers can offer a more convenient form of teaching that considers the needs of students.
		Curatr Moodle	3- help teachers to foster a deeper learning process with more engaging courses
	Internet of Things (IoT)	Smart classroom environment devices	1- Facilitates interactions among students and teachers and can accelerate the understanding of concepts .
		Attendance systems	2- improve the quality of education and satisfaction of students
		Real-time feedback on lecture quality	3- Sensing and monitoring technology used to determine student reaction to a lecture .Real time feedback is provided in order for professors to modify the dynamics of the class opportunely

4.5 Internet of Things (IoT)

"Things" refers to any equipment, servers, devices, etc., that are connected to the internet and used as independent tools that making teaching activities more efficient and attractive. Sensing and monitoring technologies are used to assess student responses to a lecture. Real-time feedback is given to allow teachers to adjust the class dynamics in a timely manner. Table III shows the M-learning types involved in the IoT tools for learning environments. These tools facilitate interactions among students and teachers and improve the outcomes of education [28-30].

5 Methodology

The aims of this research are to detect the students' feedback on the acceptance of mobile technology to the development process which possibly could enhance learning process to meet students' requirements and evaluate the quality of mobile services for academic and social purposes, as well as for determining the students'

level skill in using recent technological tools. A quantitative research methodology was used to achieve these proposes.

5.1 Instrument, participants, and data collection

In this research, we have used a quantitative methodology and an instrument (questionnaire) to gather the necessary data. An assessment sheet was prepared which contains 26 questions. The questionnaire is composite into three parts:

In the first part, the study used a 5-point Likert scale ranging from SD (Strongly Disagree), D (Disagree), N (Neutral), A (Agree), SA (Strongly Agree) to explore the students' satisfaction towards applying M-learning. In the second part, the study used flexibility scales ranging from 1 to 3, where 1- Strong Flexible, 2- Moderate Flexible and 3-Poor Flexible to explore the use of M-devices to improve student M-learning process because of their ability to facilitate access to the educational tools. Finally, in the third part, the study used scales ranging from HS=High Skilled, MS= Moderately Skilled and PS= Poorly Skilled to investigate the level of technological literacy skills of the students.

Two questionnaires were distributed among 200 students in the second and third levels in the Computer Department at Community College at Dammam, Imam Abdulrahman Bin Faisal University, and College of Arts and Science at King Khalid University, KSA.

Data were collected for two semesters of the 2018/2019 academic year. Questionnaires were retrieved and the successful questionnaires were chosen according to the following factors:

1. The respondents have used M-learning,
2. All questions have answered by the students
3. There are no inconsistent answers.

6 Results and Discussion

The percentage for each question was determined using the following equation, out of a total of 200 students who answered the questionnaire.

$$S_i\ \% = \frac{frequancy\ of\ answerw\ in\ each\ scale}{\sum frequancy\ of\ answerw\ in\ all\ scales} * 100 \quad (1)$$

Where *i* is the number of questions from 1-26.

6.1 The satisfaction of M-learning as learning tools

Table IV shows the results of the questionnaire's statements regarding the factors affecting the satisfaction of M-learning as learning tools between respondents. There are 8 statements, and the mean score for each statement was used to describe the strength of each one. In this experiment, the highest mean score is "I am satisfied with

the M-learning resources" (M=4.65). The second highest mean score is "M-learning offers continues interaction" (M= 4.525), followed by "M-learning improves my skills acquisition" (M=4.445) and "M-learning optimize the use of learning time" (M= 4.245). The lowest mean score is "M-learning very convenient to use in the future" (M= 3.99). The second-lowest mean score "is-learning Improves my ability to study" (M = 3.93). Figure 2 displays the results of the satisfaction of M-learning as learning tools.

Table 4. Satisfaction of M-learning as learning tools

Statement	SD %	D %	N %	A %	SA %	M
S1. I am satisfied with the m- learning resources	1.5	2.5	5	11.5	79.5	4.65
S2. Improves my skills acquisition	4	2.5	8.5	15	70	4.45
S3. Optimizes the use of learning time	6.5	7.5	8.5	10	67.5	4.25
S4. Improves my ability to study	4.5	4	22.5	32	37	3.93
S5. Offers continues interaction	1.5	4	6.5	16.5	71.5	4.53
S6. learning easier to review lessons anytime	4	5.5	4.5	12.5	73.5	4.34
S7. Very convenient to use in the future	3	5	16.5	41	34.5	3.99
S8. learning is exciting and engaging	14	10	17	32.5	26.5	3.48

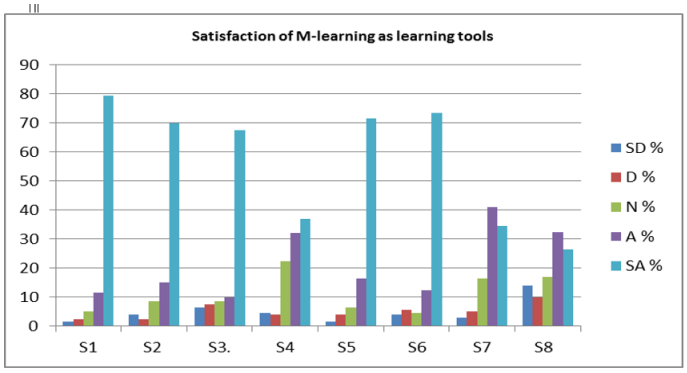

Fig. 2. Satisfaction of M-learning as learning tools

6.2 Students' perceptions towards flexibility to access M-services

The experiment depends on scales 1: 3; where 1 is Flexible, 2 is Neutral and 3 is Not Flexible, to reveal the students' perceptions on m-learning services to enhanced students due to its capabilities in facilitating accessing learning tools. Table 5 illustrates the results of the two main types of M-learning services depending on the information. There are 4 statements for assessing the flexibility of learning materials services and 7statements for administrative services based on mobile devices.

6.3 Learning materials services

The research suggested that out of the 200 respondents, 95% of the respondents have used their mobile devices for accessing the course material, and coursework (such as

course PowerPoint presentations, assignments, quizzes, etc.) whenever and wherever they go, 97% of students demonstrated that they have a strong flexible by using their mobile phones to access the schedule services and retrieving exam results during specific periods. In addition, 81% of the students found that it was strongly flexible to the use of M-learning to improve their academic performance and facilitate self-learning, while 87% of the respondents M-learning is designed to support knowledge reveals that great flexibility for M-learning to support knowledge sharing, dynamic learning activities and collaboration among students and professors through mobile devices. Figure 3 illustrates the flexibility to access M-services.

6.4 Administrative services

This study depicted that the participants confirmed have strong flexibility by using their mobile devices, 75% for automatic evaluation of lectures and professors, 86% for providing a chance of taking external and internal exams. 81% in admission services and course registrations. 60% to access library services, 70% a quick discussion of evolving ideas to manipulate teaching and research tasks. 90% for supporting different learning levels, assignments, and control the achievement of students learning outcomes. 76% for allowing merging among research and educational information environment. Figure 4 represents the flexibility of administrative M-services.

Table 5. Students' perceptions about flexibility to access M-services

Statement	Strong	Moderate	Poor
Learning materials services	***Flexibility***		
S9. Allowing continuous access of course material, and coursework functions	95 %	3 %	2 %
S10 Enabling scheduled services and checking examination results during specific periods	97 %	2 %	1 %
S11. Improving academic achievement and enable them to independent learning.	81 %	15 %	4 %
S12. Enabling knowledge sharing, dynamic learning activities and collaborative among students and Professors	87 %	11 %	2 %
Administrative services			
S13. Enabling evaluation of lectures and professors	75 %	21 %	4%
S14.Providing an opportunity of conducting external and internal exams.	86 %	10%	4 %
S15. Facilitating admission services and course registrations	81 %	14 %	5%
S16. Facilitating to access library services	60 %	21 %	19%
S17. A prompt discussion of emerging ideas to address teaching and research tasks.	70 %	18 %	12%
S18. Enable all stages of learning, gathering assignments, monitoring and control the achievement of students learning outcomes.	90 %	7 %	3%
S19. Permitting integration of research and educational information environment	76 %	10 %	14%

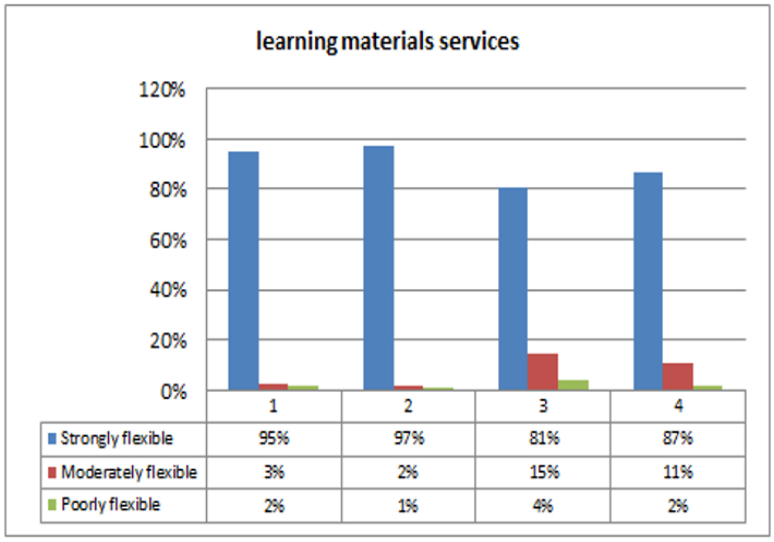

Fig. 3. Flexibility to access M-services

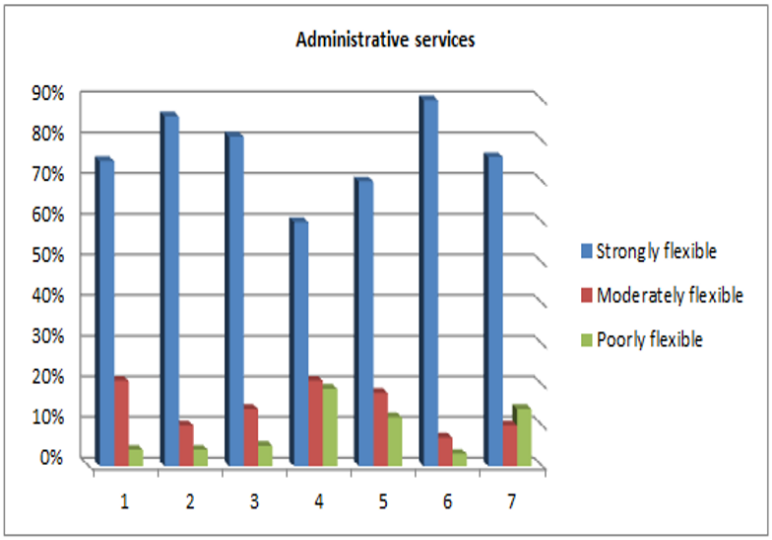

Fig. 4. Flexibility to administrative M-services

6.5 Students' level skills in technological literacy

In this research, the authors used three scales ranging from 1- Highly skilled, 2- Moderately skilled and 3- Poorly skilled to determine the level of students' skills in technological literacy. The respondents rated themselves "Highly skilled" in using M-learning at the universities that help for changing traditional learning methods

by merging M-learning methodologies. Table 6 shows the results of the proposed experiments. The research establishes that the majority of respondents 97%, "very skilled" in chatting through different social media, 92.9% YouTube, VOIP (streaming Tech), 91% M-device expertise, 86% in sending email and receiving massage, 84 % were very skilled in Downloading apps and /or Reading of e-books. 80% in research for data and information and the lowest rank was 65% to cooperate with others through Video Conferencing. The experimental results of this research are shown in Figure 5.

Table 6. Level of students' skills in technological literacy

Statement	Skilled		
	Highly	***Moderately***	***Poorly***
S20. M-device expertise	91 %	7 %	2 %
S21. Chatting using social media	97 %	2 %	1 %
S22.Sending e-mails and receiving massages	86 %	13 %	1 %
S23. YouTube, VOIP (streaming Tech)	92%	7 %	1 %
S24. Video Conferencing	65 %	17 %	18 %
S25. Downloading apps and /or Reading of e- books	84 %	10 %	6 %
S26. Researching	80 %	9 %	11 %

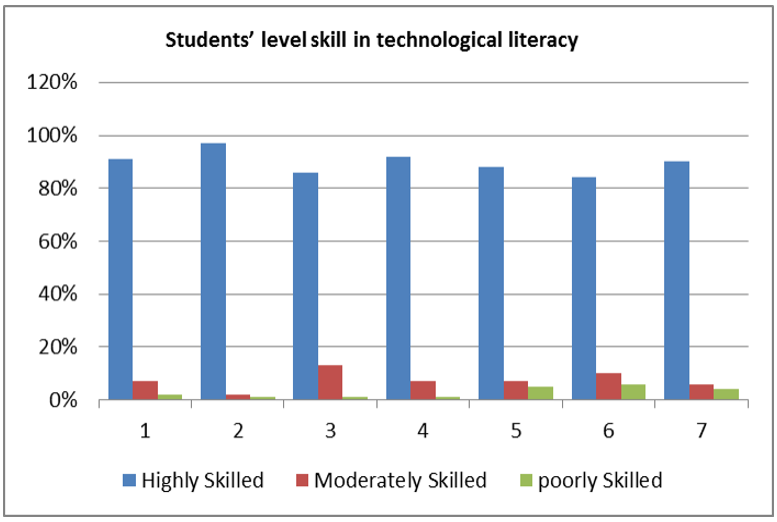

Fig. 5. Level of students' skills in technological literacy

7 Conclusion

This research introduced a study on E-learning using mobile technology and identified students' perceptions in the acceptance of mobile techniques and the quality of mobile services for academic and social purposes to improve teaching and learning performance and outcomes in higher educational institutions. The research study conducted at both Imam Abdulrahman Bin-Faisal, and King Khalid universities. A total

of 200 undergraduate students from two universities have participated in the research study. The outcomes of this study supported the development of M-learning at the universities and help for changing traditional learning methods by merging M-learning methodologies as a learning management system that provides mobile learning services to students and teachers at any time and from any location. The research study has shown some important results towards the integration of mobile technology into teaching include: student positive perception, facilitates student concentrate, access flexibility to m-services for learning materials, and increase student' skills in using mobile technology for e-learning.

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ìSPEAK: Using Mobile-Based Online Learning Course to Learn 'English for the Workplace'

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Abstract—Due to the rise of the digital era, various industries demand employees with a proficient communicative English skills, but many are still not up to par with the demands. One solution for this is to provide communicative English trainings for employees, especially support staffs, yet face-to-face trainings have many limitations, which can be overcome through mobile learning. Due to the fact that mobile learning can be accessed anytime and anywhere by anyone, the Massive Online Open Courses (MOOC) is one of the platforms that can be used to curb the issue. This paper aimed to identify the perceptions of support staffs towards using 'ìSPEAK: English for the Workplace' in MOOC. A total of 30 respondents were selected through purposive sampling and a survey through a 4-point Likert scale questionnaire was given out. The main findings showed that overall, the support staffs have a positive attitude towards using ìSPEAK. Nevertheless, half of them were unsure of the reliability of the sources available in the course. However, the findings of this study implied that ìSPEAK could be one of the training alternatives for support staffs to improve and increase their communicative ability. Future research can look into designing and developing various modules of communicative English in various mobile learning platforms, which could cater to different levels of proficiency of learners.

Keywords—Communicative English; English for the Workplace, MOOC, self-paced learning, support staffs, technology-enhanced language learning

1 Introduction

In this new digital era, aside from the rapidly evolving technologies, the status of the English language as a global language is irrefutable. The importance of mastering the English language has been emphasised in many non-native countries as a means of communication [1], [2]. Employers are keener on hiring employees with good proficiency in the English language. This is due to the fact that in order to bring an organisation up, relations with international organisations is crucial, which requires interaction with foreigners [3], [5]. Hence, the only means of communication with people of different mother tongues is through the use of English.

Yet, even in this 21st-century world, many employers complained that their employees do not possess the required proficiency in communicative English [6], [8]. The lack of English proficiency among employees causes an organisation to not be able to rise to its potential. Due to that, communicative English training for employees, especially support staffs is important. However, looking at the busy schedule and working commitments throughout the year, certain employers find it difficult to conduct trainings to improve their employees' communicative English. This is because trainings need to be comprehensive and relaxed [4] so that the employees do not feel stressed in learning communicative English.

Hence, to curb the issue of time constraint, exploiting technology can be an alternative [9], [10]. An open learning platform can be used as a substitute for face-to-face training. Open learning platforms, such as the Massive Open Online Courses (MOOC) has been recognised worldwide as a free learning platform. It has various benefits which include being free, open and allows learners to learn at their own pace [11], [12]. The fact that everyone has their own mobile device [13] is also an advantage and should be fully utilized when it comes to learning. One of the MOOC courses available to improve the communicative English of employees is known as 'ìSPEAK: English for the Workplace', which is hoped to be able to provide a better learning experience for employees to improve their communicative English as they are learning at their own pace. To further improve this course in MOOC, this study aimed to identify the perceptions of support staffs towards using ìSPEAK, an online self-paced learning module to improve communicative English for the workplace.

2 Literature Review

2.1 Self-paced learning

In this globalized era, education is not only restricted to classroom learning. Self-paced learning brings the meaning of learning independently, in which lesser interaction happens between the teacher and student [14]. One of the reasons for the arising need in self-paced learning is due to time constraint [15]. This is because, most of the learners are occupied with their own routine, so they have lesser time to learn a new skill. Learners who are working gain more benefits from this self-paced learning. Working learners have a tight working schedule, whereby they need to balance between their job prospects and time for family [15]. These learners do not have much time to go for classes to learn a new language or skill. With the worrying scenario of the decline in English language proficiency among workers [16], employers either provide training for their staffs or they will find new staffs to replace the old ones. Due to that, MOOC has been an uprising platform for learners to learn a new skill or language independently at any place and time [17], [19].

2.2 Self-paced learning through MOOC

In self-paced learning through MOOC, learners are more prone to complete a course if it is not too lengthy [20], [22]. This is because a lengthy course will make learners feel bored and they might feel burdened as they have to juggle between their job time and learning independently. Learners who find MOOC to be burdening tend to drop out of MOOC without completing the course [21]. These dropout learners prefer a more relevant and shorter course which they can learn in their own pace and the outcome is achievable. Plus, learners are not able to commit their time for MOOC because of their non-supportive learning environment. Learners who are pressured by their surroundings in working, such as having tight working schedules and non-supportive employers will affect their completion rate in MOOC too [20].

The main reason for the success of self-paced learning is because employees feel more appreciated [23]. Additionally, with the support from employers, employees are more willing to learn by themselves to develop their professionalism to suit the demand of the working field, which could also benefit the organization [23], [24]. Other than employers' support, the reason for self-paced learning is also due to the MOOC's characteristic, which is openness. Some studies have shown that MOOC provides an open, flexible and easy to access platform, which is suitable for everyone and can cater to the workers' needs [25], [28]. Findings from previous studies showed that learners have different intentions to use MOOC. Learners with the goal of lifelong learning, such as to improve their skills for employability in the future will have a positive attitude towards MOOC [29], [30]. Some learners also enrol in MOOC because they want credits for their courses [31]. Regardless of the reasons for learners' enrolment in MOOC, the factors which keep learners learning in MOOC are more important. Factors such as easy to use and useful are usually the crucial reasons [32], [33] other than being reliable, accessible and provides a comfortable learning environment [31]. Plus, learners who are positive towards learning through MOOC tend to have a higher completion rate of the online course [34] and learners are more attracted to MOOC if they have their own autonomy in choosing what they want to learn first [35], [36]. However, a study reported findings that showed that learners, especially older learners, prefer MOOC to be used as an addition to their traditional face-to-face training because the learners are unexposed to the proper ways in accessing materials in MOOC effectively [37]. But, in this digital era, technology is not an alienated tool anymore [9], [38].

Hence, in order to identify learners' thoughts towards MOOC, the technology acceptance model (TAM) is used as the framework, whereby variables of perceived usefulness (PU), perceived ease of use (PEOU) and attitude towards using (ATU) MOOC are identified. This is due to the fact that, despite being in the 21st-century era, the challenges of using technology such as low computer literacy, insufficient resources and inaccessible online materials which were a barrier back then [39] are still the barriers now to some older users [40], [42].

2.3 The use of mobile for learning

With a lot of technologies available, mobile phones are the most common tool which is possessed by almost everyone [13]. Mobile phones, which were initially used for communication purposes are now being used in learning. The changes in features of mobile phones through the years have made it possible to induce learning in a mobile form [43]. The term mobile learning or m-learning has become popular among researchers, whereby the benefits of mobile learning is undeniable. The most important feature of mobile learning lies in its flexibility to be used anywhere and anytime [44], [45]. Additionally, mobile learning also condones to self-paced learning, which is said to provide a personalised learning environment for learners who are able to participate in the lesson freely, without any restriction. This allows learners to be more motivated and engaged in the learning [44], [46]. Hence, the advantages of mobile learning, especially mobile learning through MOOC, provides an array of benefits for learners, especially learners with working commitments.

2.4 The Technology Acceptance Model (TAM)

The technology acceptance model or TAM was developed to predict and identify an individual's perceptions towards using a technology [47]. In this model, there are five constructs known as the perceived ease of use (PEOU), perceived usefulness (PU), attitude towards using (ATU), behavioural intention (BI) and actual use [47]. PEOU and PU are related to the BI and ATU because learners or users who perceived a technology to be useful and effortless will be more prone to use it in aiding their daily tasks [48], [49]. Additionally, technology users who perceive technology to be useful will have a more positive attitude and their intention to use it regularly is higher [48]. As TAM emerges, many researchers in the technological field are more inclined towards using the model to evaluate the usability of technology because TAM is simple and easy to understand [49]. Figure 1 depicts the technology acceptance model (TAM).

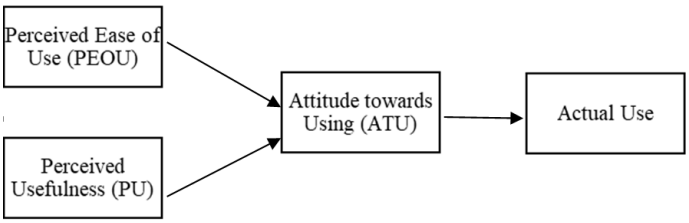

Fig. 1. The Technology Acceptance Model (TAM)

Figure 1 is the adapted version of TAM, which is adapted from Davis (1986) [48]. In TAM, the three main constructs are the Perceived Ease of Use (PEOU), Perceived Usefulness (PU) and Attitude towards Using (ATU). This means that if a user perceives a technology to be easy and useful, they will have a more positive attitude

towards using it. Then, ATU will determine the Actual Use of technology. It is also important to know whether the course is user-friendly in terms of usefulness and easy to use, which can influence the attitude and behaviour. In this case, if a user has a positive attitude towards technology, he or she will develop an intention to use it. The intention to use will affect the actual usage of the technology. Hence, this model gives an insight towards users' acceptance towards a new technological tool, which is important to know whether the users will use it or not.

3 Methodology

This empirical study employed a survey method of data collection, which consists of a 4-point Likert scale questionnaire. Respondents were chosen using purposive sampling, whereby they attended a workshop to demonstrate the usage of ìSPEAK: Communicative English Module MOOC. ìSPEAK is a Communicative English Module in MOOC, which consists of ten modules of English for workplace training as shown in Figure 2.

Fig. 2. The ten modules available in ìSPEAK

As portrayed in figure 2, the ten modules are named as module 1 to 10, which consist of the introduction, greetings, talking on the phone, making requests, offering help, giving suggestions, handling complaints, email or letter writing, show and tell (presentation skill) and conclusion respectively. Each module except the introduction and conclusion consists of four subsections. Figure 3 below shows the sample of the subsections in the modules.

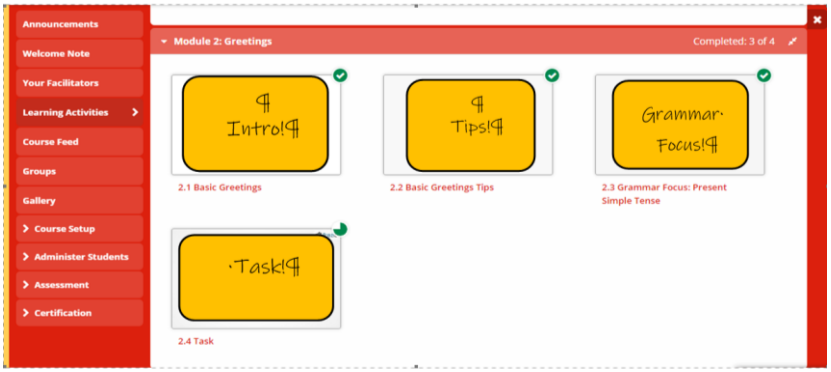

Fig. 3. Sample of subsections in Module 2

Based on the figure, it can be seen that there are four subsections for the module known as the video content, notes, grammar focus and task. All learners are required to complete the course to get a certificate of completion. Upon completion of the workshop, all 30 participants were asked to go through iSPEAK and try out all learning activities. Later, they were required to respond to a questionnaire, which consisted of 40 items, divided into four parts, which are the demographic background, with eight items, perceived ease of use (PEOU) in part 2 with six items, perceived usefulness (PU) in part 3 with eight items and attitude towards using (ATU) in part 4 which consisted of eight items. All items were adapted from Norizan and Hussein (2017) [50] and and Rosly and Khalid (2018) [51]. A pilot study was carried out to determine the reliability of this questionnaire and the Cronbach Alpha value of 0.88 showed that the questionnaire is reliable. The data were analysed using descriptive statistics in terms of percentages and frequency count.

4 Results

4.1 Perceived Ease of Use (PEOU)

Based on the survey, the data on support staffs' perceived ease of use (PEOU) towards iSPEAK were plotted into table 1.

Table 1. Perceived Ease of Use (PEOU) towards iSPEAK

Statements	Strongly disagree	Disagree	Agree	Strongly agree
I think ìSPEAK is easy to use	3.3% (1)	3.3% (1)	40.0% (12)	53.3% (16)
I think ìSPEAK is easy to master in a short time	3.3% (1)	30.0% (9)	60.0% (18)	3.3% (1)
I think ìSPEAK is easy to understand (interface and menus)	3.3% (1)	6.7% (2)	60.0% (18)	30.0% (9)
I think it is essential for learners to possess computer basic skills (e.g. saving files, creating folders) to benefit from ìSPEAK	3.3% (1)	6.7% (2)	43.3% (13)	46.7% (14)
I think it is essential for learners to possess Internet basic skills (e.g. sending emails, signing in/out, downloading/uploading files) to benefit from ìSPEAK	3.3% (1)	3.3% (1)	36.7% (11)	56.7% (17)
I need a lot of training on using computers/Internet to learn effectively through ìSPEAK	3.3% (1)	20.0% (6)	33.3% (10)	43.3% (13)

Based on the table, it can be seen that most respondents perceived ìSPEAK to be overall easy. They agreed that ìSPEAK is easy to use (93.3%), easy to master in a short time (90%) and easy to understand (90%). Despite being easy to use, a majority of them agreed that knowing the basic skills of computers is important in order to access ìSPEAK with ease (93.4%).

4.2 Perceived Usefulness (PU)

Table 2 below displayed the results for support staffs' perceived usefulness (PU) towards ìSPEAK.

Table 2. Perceived Usefulness (PU) towards iSPEAK

Statements	Strongly disagree	Disagree	Agree	Strongly agree
I think learning English through an open online course, such as ìSPEAK is useful in improving my communicative English	0.0% (0)	0.0% (0)	46.7% (14)	53.3% (16)
I think ìSPEAK can be a useful training platform for workers	0.0% (0)	0.0% (0)	50.0% (15)	50.0% (15)
I think learning through ìSPEAK can increase my productivity in learning	0.0% (0)	0.0% (0)	40.0% (12)	60.0% (18)
I think ìSPEAK is a useful tool in developing my English writing skill	0.0% (0)	0.0% (0)	40.0% (12)	60.0% (18)
I think ìSPEAK is a useful tool in developing my English reading skill	0.0% (0)	0.0% (0)	46.7% (14)	53.3% (16)
I think ìSPEAK is a useful tool in developing my English listening skill	0.0% (0)	0.0% (0)	46.7% (14)	53.3% (16)
I think ìSPEAK is a useful tool in developing my English speaking skill	20.0% (6)	26.7% (8)	26.7% (8)	26.7% (8)
ìSPEAK is able to provide effective learning resources	23.3% (7)	26.7% (8)	26.7% (8)	23.3% (7)

Referring to table 2, all respondents agreed that ìSPEAK is useful in improving their communicative English, is a useful training platform for workers, increases their productivity in learning and useful in improving their English listening, reading and writing skills (100%). However, 53.4% of the respondents agreed that ì

SPEAK improves their English speaking skills and only half of them agreed that ìSPEAK is able to provide effective learning resources (50%).

4.3 Attitude Towards Using (ATU)

The support staffs' attitude towards iSPEAK were displayed in table 3 below.

Table 3. Attitude towards Using (ATU) iSPEAK

Statements	Strongly disagree	Disagree	Agree	Strongly agree
I am eager for learning communicative English through ìSPEAK	0.0% (0)	6.7% (2)	43.3% (13)	50.0% (15)
Using ìSPEAK to learn communicative English is better than using the traditional instructions	0.0% (0)	3.3% (1)	66.7% (20)	30.0% (9)
I really need ìSPEAK to improve my communicative English	0.0% (0)	0.0% (0)	56.7% (17)	43.3% (13)
I like to chat through the ìSPEAK forums	0.0% (0)	6.7% (2)	56.7% (17)	36.7% (11)
Learning communicative English through ìSPEAK makes me nervous	16.7% (5)	43.3% (13)	26.7% (8)	13.3% (4)
Learning communicative English through ìSPEAK is not interesting	36.7% (11)	33.3% (10)	16.7% (5)	13.3% (4)
Using the ìSPEAK to learn communicative English bothers me	33.3% (10)	40.0% (12)	13.3% (4)	13.3% (4)
Using the ìSPEAK to learn communicative English scares me	43.3% (13)	30.0% (9)	13.3% (4)	13.3% (4)

Based on the results from the survey as plotted in table 3, it can be seen that a majority of the respondents have positive attitude towards using ìSPEAK as they are eager to learn with ìSPEAK (93.3%), they like it as it is better than traditional instructions (96.7%) and they like to chat through the forums (93.4%). All of the respondents responded that they need ìSPEAK to improve their communicative English (100%).

5 Discussion

The findings showed an overall positive perception of support staffs towards using ìSPEAK. The most crucial factor which contributes to the positivity lies in the usefulness of MOOC [26]. As can be seen, a majority of support staffs perceived ìSPEAK to be useful in assisting them in learning Communicative English for the Workplace. This is deemed important because a tool which is perceived to be not useful will not be used by learners. Not only that, MOOC as mentioned in many studies, is undeniably useful as it allows learners to learn at their own pace, which will indirectly max-

imise the learning input gained as learners are able to put more emphasis in learning at their own time rather than learning everything in one day [30], [32]. Due to that feature of MOOC, learners are interested in using ìSPEAK as it provides a useful learning environment, which could cater to various learners, especially adult learners who are working.

Next, ìSPEAK is easy to use as perceived by the support staffs. This is because MOOC has an easy interface and it also provides a tour or guidelines for first-time learners [31]. Learners find it easy to master ìSPEAK in a short time as MOOC only deals with basic computer skills such as downloading and uploading files. Regardless of that, it is important to note the targeted audience as well to ensure that the interface of ìSPEAK can be created in a user-friendly manner for those who are unfamiliar with it. Browsing through the learners' background, a learner's age might influence their perceived ease of use (PEOU) as older learners might not be a technology-savvy [41], [42]. Yet, with the current revolution, almost everyone owns a mobile phone, in which MOOC can be accessed through the applications available, which is equally convenient for everyone [9], [10].

Finally, ìSPEAK sparks positive attitudes from the support staffs. Most learners agreed that they are eager to learn through ìSPEAK. One of the reasons is due to time constraint for face-to-face learning [4]. Using MOOC, learners can access learning anywhere and anytime they want based on their own free time [30], [34], [35], [52]. Due to that, they prefer to use MOOC rather than attending face-to-face training courses. Plus, learners who are well aware of the importance of learning CE are more inclined to use ìSPEAK to improve themselves.

6 Conclusion

This paper aimed to find out the perceptions of support staffs towards ìSPEAK. The findings reported positive perceptions towards using ìSPEAK as a platform for self-paced learning. However, some learners are still unsure of the reliability of the resources available in ìSPEAK, either they are useful for their workplace or not. Thus, this paper implied that employers can look into alternatives to improve their staffs' communicative English by encouraging them to enrol in ìSPEAK. In the future, research can look into designing and developing various modules of communicative English in various platforms, which could cater to different levels of proficiency of learners. With that, online open learning can be an educational tool which could be an alternative learning platform for everyone especially in encouraging self-paced learning.

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Mobile Simulator Control System for Isolating Breathing Apparatus of Software-Hardware Platform

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Abstract—The current problem in the process of training miners is to ensure the mobility and the ability to perform exercises not only on simulators, but also in real conditions of the mine. Therefore, the software and hardware platform of the training complex should include not only imitators of isolating breathing apparatus for developing proper breathing skills in self-rescuers, but also mobile control systems. This will allow carrying out the learning process in conditions similar to real, will increase usability by eliminating wired data transfer interfaces. In addition, the mobile control system of the simulator monitors the trainee's state indicators in real time in an understandable form for him on a wristband or watch. For the implementation of software and hardware of such system, appropriate structural and functional models were developed, including patterns of interaction between components, data transfer and processing processes. On their basis, a software and hardware implementation of a mobile simulator control system is carried out. The results can be applied in the development of mobile controls in various software and hardware platforms.

Keywords—Mobile control systems, training complexes, breathing apparatus simulator, Android.

1 Introduction

At present, training complexes are actively used for training personnel for professional-use ergatic systems: miners of the mining industry [1], employees of industrial enterprises [2], medical personnel [3], military personnel [4], etc. We note that in a number of areas of human activity, it is not realistic enough to model virtual reality and interaction with it. In order to achieve high-quality learning results in such cases, it is necessary to introduce specialized equipment into the training complex - physical exercise simulators, breathing apparatus [5] [6] [7].

The application of such simulators only in prepared premises for personnel's training does not always allow developing the correct set of competencies, visual and physical sensations. In addition, the use of wired simulators, permanently connected to a computer or a control station, significantly limits the freedom of movement of the student. It should also be noted that the transition of virtual reality equipment to a wireless data interface leads to the need to completely abandon the wired connection

for all components of the simulator [8] [9]. Thus, the actual task is the transition to mobile simulators and, consequently, mobile control systems [10]. The solution of this problem will allow training not only in specially prepared premises, but also at test sites, in mines, without restricting the user to wired interfaces.

Within this article, a block diagram of a mobile control system for a simulator of isolated breathing apparatus (IBA), its algorithmic support and software, and its integration into a software and hardware platform of a training complex are considered. Thus, for the first time, a mobile control system based on a wristband or smart watch was developed for this kind of simulators, which opens up new possibilities for wireless and portable control of equipment of training complexes.

2 Analysis of Design Features for Mobile Platforms

At the first stage of the implementation of the mobile control system of IBA simulator, an analysis of existing approaches to its software and hardware implementation was accomplished. The first prototype of the system was implemented on the basis of a controller for the realization ESP32 mobile control devices with built-in Wi-Fi and Bluetooth 4.2 modules, as well as a Nextion touchscreen [11] [12]. This design made it possible to solve the main problems of IBA simulator control; however, it had a number of significant drawbacks: large dimensions and weight, the need to manufacture a complex-shaped body, short operating time and its instability. Therefore, in the course of research, it was decided to switch to a ready-made software and hardware solution based on a popular operating system to reduce the total cost of development and the possibility of using it on a wide range of devices [13] [14].

The use of consumer fitness trackers of physical activity was considered as a possible solution [15]. However, proprietary operating systems installed on such devices greatly complicate the process of developing and integrating such platforms into training complexes.

The following operating system options were considered: Android, Wear OS, iOS, Tizen. For each option, there are a sufficient number of wristwatch versions with the necessary autonomy, computing power, compact size [16] [17] [18] [19].

The conducted analysis of the features of development for these mobile platforms showed that for iOS operating system there are a number of limitations during developing and installing applications, accessing sensors of the device, and the need to interact with iOS-based smartphone [20]. Also, the total cost of the hardware platform compared to the other options remains quite high.

Devices based on Tizen have open access to sensors [21] [22], are quite common, have a lower cost, however, the development for this operating system does not allow you to quickly transfer the resulted solution to other platforms. The restriction is also orientation to the round format of the interface. However, the use of Tizen is generally justified for this kind of control systems and may be considered in the future.

Wear OS platform (formerly Android Wear) also provides the necessary software package of libraries for working with sensors and transmitting data via wireless inter-

faces [23]. The resulted software solution can be quickly ported to a full version of Android. The cost of solutions based on this platform is also relatively low.

The research also considered the option of a smart watch based on Android [24] [25]. Compared with the previous version, these devices have slightly worse autonomy; however, they work on a full-fledged operating system without any restrictions. The applications developed for this platform are automatically operable on any Android devices. Testing and installing applications do not require any additional funds, except the environment development. The cost of solutions based on this operating system is also one of the lowest.

Therefore, in the course of the analysis, it was decided to use the devices on the full-fledged Android operating system as a software and hardware platform for the mobile control system of IBA simulator. In the future we plan to port software to Wear OS and Tizen, which will significantly expand the range of possible devices.

3 Structural Diagram of Mobile Control System for IBA Simulator

Having determined the platform on the basis of which the mobile control system of IBA simulator will function, we proceed to the development of a general structural scheme. The main hardware component of IBA simulation system is a self-rescuer simulator, the structure and interaction of which components are presented in Figure 1.

The simulator is similar in appearance to the self-rescuer, all actuators are located in the shell of the cartridge. The control unit, installed inside the simulator, receives control signals from the mobile system and transmits data about the current temperature of the heating unit, the level of regulation of the resistance to breathing [11]. Thus, despite the isolation and independence of the self-rescuer simulator, an external control system is required for its full-fledged work.

The main components of the mobile control system for IBA simulator are considered:

1. **Mobile platform**: Hardware and software system in the form of a wristband or watch based on Android operating system with the ability to store data and play text, graphic or audio information.
2. **Software control system**: It includes all the necessary business logic of IBA simulator control system, used to get data from sensors to an output device (display).
3. **Pulse sensor**: Integrated into the mobile platform heart rate sensor with the ability to obtain data from it using the program code libraries.
4. **Wi-Fi module**: The component of the mobile platform used to obtain information from the control unit of the self-rescue simulator about the current breathing resistance, temperature of GBM, and other parameters. It is also used to transmit control signals to IBA simulator.
5. **Power supply**: Built-in battery of the mobile platform, ensuring its functioning for the required period of time.

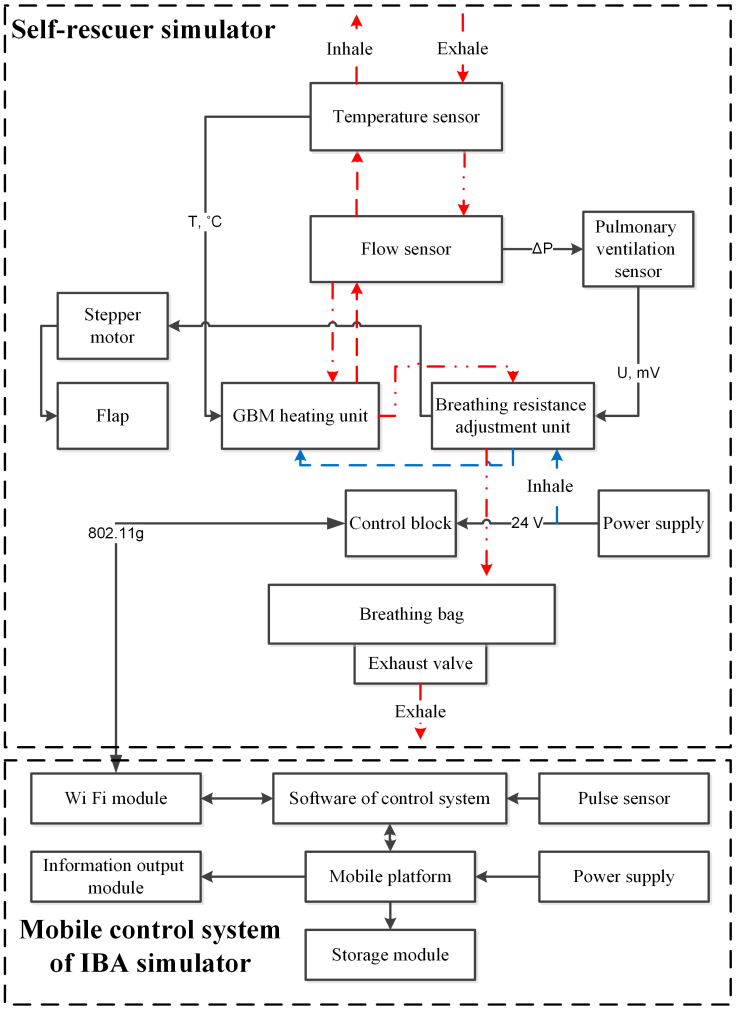

Fig. 1. Structural diagram of mobile control system for IBA simulator

6. **Output information module**: The component of the mobile platform in the form of a display module that receives information from the microcontroller. The data should be visualized in a user-friendly format. You also need to display the control elements on the screen - buttons and adjustment elements, the interaction with which is converted into control signals for the simulator.
7. **Storage module**: Built-in or external flash-memory used to write and read files containing complete information about the entire training process on the simulator. This type of memory is compact, energy efficient and widespread.

Thus, the obtained structure of the mobile control system of IBA simulator will allow organizing the collection, processing, storage and display of data from IBA simulator, as well as ensure its integration into training complexes of various types.

4 Algorithm of Functioning of Mobile Control System of IBA Simulator

It is necessary to implement the corresponding algorithms formalized in the form of a functional diagram in IDEF0 notation (Figure 2) for the correct functioning of the software of the mobile control system of IBA simulator. We carry out the decomposition of the main stages of functioning of a mobile control system of IBA simulator.

At the first stage (A1), the instructor turns on the simulator in accordance with the technical conditions of its operation. Conditions include the ambient temperature and humidity, the absence of a powerful electromagnetic field, the charge level of the power sources of IBA simulator and the control system. If, after switching on, the simulation system provides information about its readiness for further work, the instructor can proceed to the next stage.

After successful switching on, the diagnostics of the mobile IBA imitation system begins to verify the correctness of its operation (stage A2). Diagnostics includes checking both the hardware and software of the mobile control system of IBA simulator. In case of successful completion of the built-in diagnostic routine, the simulator should contact all external components: the simulator control system, the software of the training complex. After the connection is established, the system performs a test run and sets the initial value of the flap opening and the temperature. These values should be sent to all devices connected to the simulator - to the wristband and personal computer of the instructor. In case the errors are detected during the diagnostics, the system is restarted. If the failure is not fixed in this way, diagnostics is carried out with the involvement of a group of software and hardware developers. If no errors are detected during the diagnostics, the instructor proceeds to the next step.

At the third stage (A3), the instructor downloads a training protocol into the mobile control system of IBA simulator, which includes all the necessary information to manage the training process and the simulator. After successful loading of the protocol, parallel execution of stages A4-A6 begins.

Stage A4 includes the implementation of the learning protocol itself. This process means the timely, predetermined control of the position of the valve and the temperature of the heater, at which the trainee will experience the breathing resistance required at the moment of the training scenario, as well as inhale GBM of a given temperature.

Stage A5 is responsible for tracking the learning process itself. The system records in the database all the errors made by the student, the frequency of their occurrence, so that later on during the training it was possible to correct the exercise in order to test the students' weaknesses [26].

Stage A6 is related to tracing student performance. These include the physical characteristics of a person - spirogram, pneumotachogram and pulsogram. These indicators are also displayed graphically on the simulator and on the wristband. The definition of physical indicators is carried out in separate software modules based on the specified mathematical relationships.

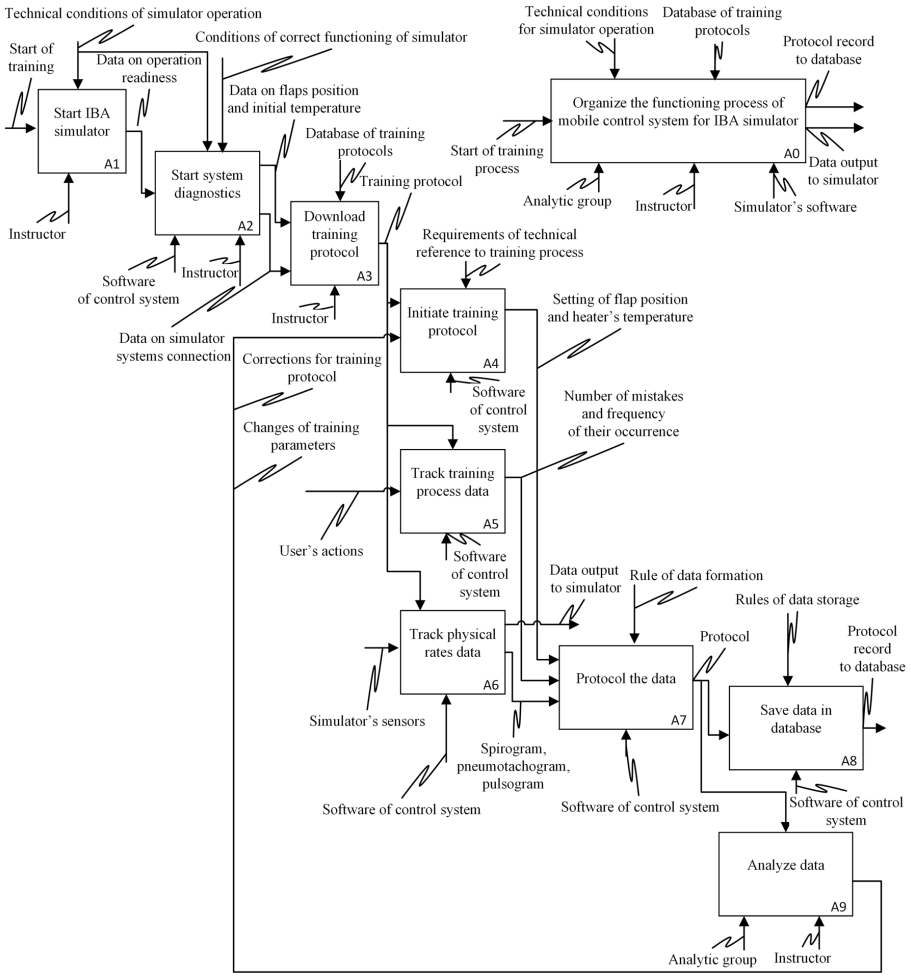

Fig. 2. Functional model of system with IBA simulator

The output data of stages A4-A6 are logged during stage A7. According to the obtained data, some parameters of the student are calculated, for example, the time of the protective action of the self-rescuer simulator. The data, collected from various sources, are standardized, processed, and then saved as files.

In addition to the files, the learning result is also stored in the database at stage A8. In the future this will allow us to provide more convenient processing and searching for information, to import the collected data into other information systems.

Stage A9 summarizes the learning process. The collected data is analyzed, the effectiveness of training, its impact on the person's performance are evaluated. If the training did not have a sufficient effect or a large error was detected during the course of the training, an additional briefing is conducted with the trainee, and the training scenario is adjusted to develop the required skills (the adjustments are applied at step

A4). If after the training, the student repeatedly shows a discrepancy to the standards of training, a conclusion is made about the professional unsuitability of the employee.

The algorithmic support presented within the framework of the developed functional model will make it possible to correctly organize the control of IBA simulator on the basis of a mobile platform, to collect and analyze data on the physical state of the student.

5 Practical Implementation of Mobile Control System for IBA Simulator

The stated structural and functional models of the mobile control system of IBA simulator were used for its software implementation based on a wristwatch on Android operating system. The software fully implements the algorithms presented in the functional model.

Launched on smart watches, the software of the mobile control system of IBA simulator is presented in Figure 3.

Fig. 3. Mobile control system interface of IBA simulator

The developed software is designed to control the basic parameters of a self-rescuer simulator: heater temperature and the flap opening value to create the required breathing resistance, as well as collecting basic information about the simulator operation. Using a ready-made software and hardware platform in the form of a smart watch allows you to measure the user's current pulse on the built-in sensor.

Data is received from the simulator control unit through the UDP protocol. Data comes in the form of a set of bytes. The following program code is used to convert them into a user-friendly form:

```
  byte[] buf = new byte[1024];
  DatagramPacket packet = new DatagramPacket(buf,
buf.length);
  socket.receive(packet);
  byte[] data = packet.getData();
  int temp_arz = (((data[0] & 0xFF) * 256) + (data[1] &
0xC0)) / 64;
  if (temp_arz > 511) { temp_arz -= 1024; }
  temperature = temp_arz * 0.25f;
  int pressure_raw = ((data[2] & 0xFF) << 8) + (data[3] &
0xFF);
  pressure = (((pressure_raw - 1024) * 500 * 2.0f) /
60000.0f) - 500;
  int temp_raw = ((data[4] & 0xFF) << 8) + (data[5] &
0xFF);
  inner_temp = (temp_raw - 10214.0f) / 37.39f;
```

The variables *pressure* and *inner_temp* determine the amount of the flap opening and the internal temperature in the simulator. The formulas for their calculation are obtained by empirical method and confirmed by repeated tests and comparisons with the values obtained on the installation of artificial lungs.

The developed software installed on wristwatches was successfully integrated into the training complex for training miners in the mining industry and allows them to be trained not only in specialized premises, but also directly in mines, at testing sites without restriction on the user's movement.

6 Conclusion

Modern training complexes are developing in the direction of increasing their compactness, mobility, and the transition from wired to wireless data transmission interfaces. In some subject areas, for example, in the mining industry, in addition to the realization of interaction with virtual reality, the integration of physical stress and respiratory imitation systems is required.

This article discusses the problem of wireless interaction organization with IBA simulator using a mobile control system. The application of the proposed system will solve a number of urgent problems: to implement training not only in unprepared premises, but also in landfills or mines, increase the student’s mobility, organize wireless data collection and processing about the process of interaction with the simulator without computers, monitor the learner’s performance in real time on wristband or watch.

In order to solve the set problems, an analysis of the specifics of design for mobile devices was carried out, which allowed determining priority platforms for implementation of a mobile control system. At this stage of research, Android was selected as the main platform for development of a mobile system, and in the future the list of operating systems is planned to be expanded.

Structural and functional models used for the software implementation of a mobile control system for IBA simulator are developed. The presented models were used in the formation of the structure and business logic of software, the organization of interaction between modules and the integration of a mobile system into the learning process. A software code is presented for collecting and processing data, obtained from a self-rescuer simulator. The stated scientific and practical results can be used to solve equipment control problems in training complexes from mobile devices.

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A Comparative Study of Machine Learning Methods for Automatic Classification of Academic and Vocational Guidance Questions

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Abstract—Academic and vocational guidance is a particularly important issue today, as it strongly determines the chances of successful integration into the labor market, which has become increasingly difficult. Families have understood this because they are interested, often with concern, in the orientation of their child. In this context, it is very important to consider the interests, trades, skills, and personality of each student to make the right decision and build a strong career path. This paper deals with the problematic of educational and vocational guidance by providing a comparative study of the results of four machine-learning algorithms. The algorithms we used are for the automatic classification of school orientation questions and four categories based on John L. Holland's Theory of RIASEC typology. The results of this study show that neural networks work better than the other three algorithms in terms of the automatic classification of these questions. In this sense, our model allows us to automatically generate questions in this domain. This model can serve practitioners and researchers in E-Orientation for further research because the algorithms give us good results.

Keywords—Academic and vocational guidance, E-orientation, Machine learning, Automatic classification, Comparative study.

1 Introduction

The classification of questions is a problem that has already been studied by several researchers in this field, but most of the work is domain-specific or limited to a high-level classification.

Anbuselvan and R.Ahmed [1] proposed an SVM-based method for the same task. The question is first analyzed and numbered, the parts of the speech are labeled, the stop words are deleted, the data is truncated and many features are extracted. The feature selection steps are performed prior to transmitting the data to a carrier vector machine for training. The same treatment is also done for test questions, which can take a long time to get results in real-time.

Marco Pota [2] propose a feature-based method, in which features related to a subset of questions such as keywords, how - all / some words, leading verbs and various other such features were extracted from the texts a classifier.

For Natural Language Processing (NLP) Convolutional neural networks (CNNs) have already been used in some works. Collobert and J.Weston [3] first proposed the idea of a convolutional neural network architecture, which includes lookup tables and hyperbolic hard tangents. Kalchbrenner and P.Blunson [4] proposed a simplified version of Collobert's network, which was used to classify Twitter's questions and opinions. They used the concept of k-max pooling. Yoon Kim [5] developed Kalchbrenner's work to add various machine-learning strategies, such as regularization, to improve network performance.

For the time, the question classification has mainly been studied in the context of open-domain TREC (Text REtrieval Conference) questions [6], with smaller recent datasets available in biomedical [7] [8] and education [9]. The TREC corpus of questions from the open-domain is a set of questions associated with a taxonomy developed by Li and Roth [10] that includes 6 types of coarse responses (such as entities, locations, and numbers) and 50 fine-grained types (for example, specific types of entities, such as animals or vehicles). While a wide variety of syntactic, semantic and other features and classification methods have been applied to this task, culminating in an almost perfect classification performance [11], recent work has shown that QC methods developed on TREC issues usually fail to transfer to datasets with more complex issues such as those in the biomedical field [7], probably due in part to the simplicity and syntactic regularity of questions and the possibility of simpler term frequency models achieve near-ceiling performance [12].

In this world, the educational and guidance system of each country seeks to help the students or the laureates of higher education institutions and vocational training institutes to make their choice.

According to Ali Boulahcen [13] and through his analysis, he noticed that there is no real process of educational guidance in Morocco, but there is only a summary process in the context, within a few seconds, one decides on the fate of the pupil that based solely on his academic value then translated by a numerical note.

This means that the Moroccan school institution is based at least on selection criteria and not on orientation [13]. In this context, our goal is to set up an E-Orientation system that is interested in the automation of the orientation task, thanks to the evolution of information technologies. The realization of this electronic guidance system requires the classification then modeling and integration of user preferences in this system. In this paper, we used the Multi-Class Neural Networks algorithm to classify the different questions according to John L. Holland's RIASEC topology.

This document is organized as follows: Section 2 is devoted to a review of the literature of different theories of educational and vocational guidance, including the theory of John L. Holland. Section 3 is devoted to the various algorithms for the automatic classification of text that we will use in our model. Section 4 deals with the experimental evaluation of each classification algorithm with the results obtained. Finally, section 5 covers the conclusion with research perspectives.

2 Related Work

The guiding approach is based on theories and studies related to career choice and career development. These include Hoyt's concept of career education, Gardner's theory of multiple intelligences and Holland's typology of professional interests [14]. Holland's theory of vocational choice (1997) [15], is the result of the work of American psychologist and researcher "John Holland (1919-2008)". The results of his research argue that their skills, interests, and personality would determine the association of workers to one type of career.

Some activities would be better suited to one type of person than another would. It constitutes the theoretical anchoring of our classification model and serves as a basis for many psychometric tools, including the Hexa 3d professional interest's questionnaire. Although this theory, dating from the mid-1960s is still widely used [16] and has been the subject of numerous studies [17], [18].

To briefly explain his theory, Holland (1997) [15] formulates several hypotheses according to professional interests that are a mode of expression of personality. Therefore, he considers the choices of orientation as a mode of expression of this personality and distinguishes six types of personality (RIASEC), according to aptitudes, personality traits, values, and beliefs.

Of all the models related to career development, the Holland model has been the subject of the greatest number of analyzes and studies.[19]. Among those conducted on the structure of interests across gender and ethnic populations, a number demonstrates the consistency of the arrangement of types and their proximity on a hexagonal and spherical model [18], [20], [21]. This debate focuses more on the geometric regularity of the hexagon and on the correspondence distances between the different types. Vrignaud and Bernaud (1994) validated other things such as the structure of the Holland model in France [22].

Professional activities, as well as work environments, tend to bring together people who share common interests to a certain extent. The choice of a profession or trade is a form of expression of the personality of an individual; it is the theory of vocational interests. As well as, the person-work environment combination is the most widely used method in the world of educational and vocational guidance.

The theory of vocational choice distinguishes six categories of professional interest (realistic, investigative, artistic, social, enterprising, and conventional) corresponding to different personality profiles. Holland represents them according to a hexagonal model illustrated in Fig.1 [23].

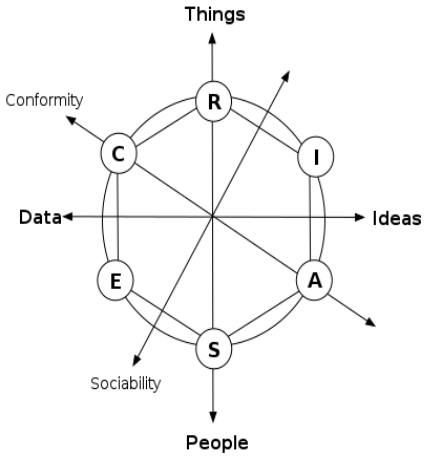


Fig. 1. Representation of Holland's circular Model (RIASEC)

According to Holland's theory and previous research, they have confirmed the profession or trade chosen by a person which is a form of expression of his personality. Therefore, it is related to the type to which he belongs.

The affiliation of a worker to one of the six types would be determined by his aptitudes, by certain traits of his personality and interests. So, according to Holland, people of the same type would be attracted to the same kind of work. Why? Because these people are similar in their personality, in the fact they pursue similar objectives and have the same physical or psychological dispositions with regard to their work. All persons can be divided into six professional types.

The typology of a person is established by measuring his degree of affinity with each of the six types, to place them in order of importance, of the type that corresponds most to him. For most people, it is mostly the first two or three types of personal classification that determine their way of being and acting in their personal and professional lives. For example, a person whose dominant type is "Investigator" and who has affinities with the "Realist" type; we will say that he has an "IR" profile. To further characterize this person's typology, it is possible to consider the third type which it most closely resembles and to say the case where it is of the "Social" type and is this person has an "IRS" profile?

These types can be combined in all sorts of ways and their combination determines the personality.

- **The Realistic type**: People of this type take pleasure in carrying out concrete tasks. Adroit with their hands, they know how to coordinate their actions. They are happy to use tools, are adept at appliances, machines, vehicles. No problem to tinker or repair what is down. Realists often have a sense of mechanics and precision. Many practice their profession outdoors rather than indoors. Their work often requires good physical stamina and even athletic abilities.

- **The Investigator type**: Most investigators are not afraid of "theory", on the contrary. They like to collect data, make assumptions, look for solutions to solve problems as we do in maths. The "investigators" take the time of the observation; they are often "secondary" unlike the impulsiveness that acts without taking the time of the analysis. So, they like to be absorbed in their thoughts, play with ideas. In the work, we appreciate their intellectual rigor and their sense of method, but as a team, their character may seem a bit cold and distant.
- **The Artistic type:** Artist profiles are interested in creative work, be it visual art, literature, music, advertising or theater. Independent and non-conformist, they are comfortable in situations that are out of the ordinary. They are endowed with great sensitivity and imagination. Although they are discouraged by methodical and routine tasks, they are nevertheless able to work with discipline to perfect their artistic talent and to carry out long-term work.
- **The Social type:** People of this type like to be in contact with others in order to help them, to inform them, to educate them, to entertain them, to treat them or to promote their growth. They are interested in human behaviors and are concerned about the quality of their relationships with others. They use their knowledge and their feelings and emotions to act and interact.
- **The Entrepreneurial type:** People of this type like to influence their surroundings. Their decision-making ability, sense of organization and a particular ability to communicate their enthusiasm support them in their goals. They know how to sell ideas as much as material goods. They have a sense of organization, planning, and initiative and know-how to carry out their projects. They know how to be bold and efficient.
- **The Conventional type:** People of this type have a preference for specific, methodical activities that focus on a predictable outcome. They are concerned about the order and the good material organization of their environment. They prefer to conform to well-established conventions and clear instructions rather than to act with improvisation. They like to calculate, classify, maintain registers. or folders. They are effective in any job that requires accuracy and ease in routine tasks.[24].

3 Materials and Methods

Classification systems for the best-performing questions tend to use a rule-based custom template matching [25] [11], or a combination of basic learning approaches. of rules and machine learning [26], to the detriment of model construction time.

Recent research on the methods learned has shown that a large number of CNN variants [27] and LSTM [12] achieve similar precision on the TREC question classification; these models presenting at best small gains compared to simple models. Term frequency models. These recent developments echo the observations of Roberts and M.Fiszman [7], who have shown that existing methods beyond term frequency models fail to generalize to questions in the medical field.

In the education sector, researchers Godea. A and Nielsen.R [9] collected 1,155 questions in class and classified them into 16 categories. To allow a detailed study of the classification of questions in the scientific field.

The process of classifying a text collection is to label each text with one or more predefined classes (Categories). In this process, an algorithm is first designed then it is driven with a set of specific characteristics, for example, word occurrences or even theme distributions in a document. Once trained, the algorithm is used to label new texts, but these are different from the texts used during training. The algorithm is evaluated on the number of classification errors obtained during the learning phase and during the test phase.

When we are training the classification algorithm, the extraction phase of the characteristics is used for learning crucial. These Characteristics extracted from texts that are typically derived from a large vector space. This space is constructed with vector modeling of words using distributional semantics [28].

Data science or statistical algorithms are further classified into multiple machines learning specific algorithmic categories:

- Supervised learning algorithms (label and output known).
- Unsupervised learning algorithms (label and output not known).
- Reinforced learning algorithms (reward-based agent action).
- Semi-supervised learning algorithms (mix of supervised and unsupervised).

These algorithms, in turn, contain multiple sub-algorithms and types (see Table I). For example, a few algorithms fall under the category of parametric, whereas others are non-parametric. In parametric algorithms, information about the population is completely known which not the case with non-parametric algorithms is. Typically, parametric models deal with a finite number of parameters, whereas non-parametric learning models are capable of dealing with an infinite number of parameters. Therefore, the training data grows the complexity of nonparametric models increases. Linear regression, logistic regression, and Support vector machines are examples of parametric algorithms. K-nearest neighbor and decision trees are non-parametric learning algorithms. These algorithms are computationally faster in comparison to their nonparametric companions. As TABLE 1 depicts, the machine learning algorithms are large in number [29].

Table 1. Machine learning Algorithmus

Supervised Learning	Unsupervised Learning	Reinforcement Learning
Artificial neural network	Artificial neural network	Q-learning
Bayesian statistics	Association rule learning	Learning automata
Case-based reasoning	Hierarchical clustering	
Decision trees	Partitioned clustering	
Learning automata		
Instance-based learning		
Regression analysis		
Linear classifiers Decision trees		
Bayesian networks		
Hidden Markov models		

In this section, we will describe the different classification algorithms used in our research

3.1 Multiclass decision forest

The decision forest algorithm is an ensemble learning method for classification. The algorithm works by creating several decision trees and then voting on the most popular output class. Voting is a form of aggregation, in which each tree in a classification decision forest generates a non-standard frequency histogram of labels. The aggregation process adds these histograms and normalizes the result to obtain the "probabilities" for each label. Trees that have high confidence in the forecasts have a greater weight in the final decision of the set.

Decision trees, in general, are non-parametric models, which means that they support data with varied distributions. In each tree, a simple test sequence is executed for each class, increasing the levels of a tree structure until a leaf node (decision) is reached.

Decision trees have many advantages, they can represent non-linear decision limits, they are effective in calculating and using memory during training and prediction, and they perform an integrated selection and classification of features are resistant in the presence of noise characteristics.

The decision forest classifier in Azure Machine Learning Studio (Classic) consists of a set of decision trees. In general, ensemble models provide better coverage and accuracy than single decision trees.

3.2 Multiclass decision jungle

Decision Jungles are a recent extension of Decision Forests. A decision jungle consists of a set of decision-directed acyclic graphs (DAGs). The decision jungles have the following advantages; By allowing tree branches to merge, a decision DAG generally has a smaller memory footprint and better generalization performance than a decision tree, but at the cost of slightly longer training time. Additionally, decision

jungles are non-parametric models, which can represent nonlinear decision boundaries. Finally, they perform an integrated selection and classification of features and are resistant to noisy features**.**

3.3 Multiclass regression logistic

Logistic regression classification is a supervised learning method and therefore requires a tagged dataset. You train the model by providing the model and dataset labeled as input to a module such as the Train Model or Tune Model Hyperparameters. The driven model can then be used to predict the values of new input examples.

Logistic regression is a well-known method in statistics that is used to predict the probability of a result and is particularly popular for classification tasks. The algorithm predicts the probability of occurrence of an event by adjusting the data to a logistic function. For more details on this implementation, see the Technical Notes section. In multi-class logistic regression, the classifier can be used to predict multiple outcomes.

Multinomial logistic regression is a form of logistic regression, which used to predict a target variable; it has more than 2 classes. It is a modification of logistic regression using the softmax function instead of the sigmoid function, and the cross-entropy loss function. The softmax function squashes all values to the range [0, 1] and the sum of the elements is one.

$$soft\max(x)_i = \frac{e^{x_i}}{\sum_{j=1}^{n} e^{x_j}} \tag{1}$$

Cross entropy is a measure of how different 2 probability distributions are near to each other. If p and q are discrete, we have:

$$H(p,q) = -\sum_x p(x) Log\, q(x) \tag{2}$$

This function has a range of [0, inf], it is equal to 0 when p=q and infinity then p is very small compared to q or vice versa. For example x, the class scores are given by vector z=Wx+b, where W is a C×M matrix and b is a length C vector of biases. We define the label y as a one-hot vector equal to 1 for the correct class c and 0 everywhere else. The loss for a training example x with predicted class distribution y and correct class c will be:

$$\hat{y} = softmax(z) \tag{3}$$

$$\begin{aligned} loss &= H(y, \hat{y}) \\ &= -\sum_i y_i \, Log \, \hat{y}_i \\ &= -Log \, \hat{y}_c \end{aligned} \tag{4}$$

As in the binary case, the loss value is exactly the negative log probability of a single example x having true class label c. Thus, minimizing the sum of the loss over our training example is equivalent to maximizing the log-likelihood. We can learn the model parameters W and b by performing gradient descent on the loss function with respect to these parameters. There are two common methods to perform multi-class classification using the binary classification logistic regression algorithm: one-vs-all and one-vs-one. In one-vs-all, we train C separate binary classifier for each class and run all those classifiers on any new example x, we want to predict and take the class with the maximum score. In one-vs-one, we train C to choose 2 classifiers = C(C-1)/2 one for each possible pair of class and choose the class with maximum votes while predicting for a new example.

3.4 Multiclass neural network

A neural network is a set of interconnected layers. The inputs are the first layer and are connected to an output layer by an acyclic graph comprised of weighted edges and nodes.

Between the input and output layers, you can insert multiple hidden layers. Most predictive tasks can be accomplished easily with only one or a few hidden layers. However, recent research has shown that deep neural networks (DNN) with many layers can be very effective in complex tasks such as image or speech recognition. The successive layers are used to model increasing levels of semantic depth.

The relationship between inputs and outputs is learned from training the neural network on the input data. The direction of the graph proceeds from the inputs through the hidden layer and to the output layer. All nodes in a layer are connected by the weighted edges to nodes in the next layer.

To compute the output of the network for a particular input, a value is calculated at each node in the hidden layers and in the output layer. The value is set by calculating the weighted sum of the values of the nodes from the previous layer. An activation function is then applied to that weighted sum. For example, neural networks of this type can be used in complex computer vision tasks, such as recognition of numbers or letters, document classification, and pattern recognition.

Classification using neural networks is a supervised learning method and therefore requires a tagged data set that includes a label column. You can train the model by providing the tagged model and dataset as input for Train Model or Tune Model Hyperparameters. The driven model can then be used to predict the values of the new input examples.

A neural network is a set of interconnected layers. The inputs are the first layer and are connected to an output layer by an acyclic graph composed of weighted edges and nodes. We can insert multiple hidden layers between the input and output layers. Most predictive tasks can be accomplished easily with one or more hidden layers. However, Deep Neural Networks (DNNs) [30], [31] with many layers can be very effective for complex tasks such as image recognition or speech. Successive layers are used to model increasing levels of semantic depth. The relationship between inputs and outputs is learned during the formation of the neural network on the input data. The chart direction passes inputs to the hidden layer and the output layer. All the nodes of a layer are connected by the weighted edges to the nodes of the next layer.

To calculate the network output for a particular input, a value is calculated at each node of the masked layers and the output layer. The value is defined by calculating the weighted sum of the values of the nodes of the previous layer. An activation function is then applied to this weighted sum.

We use a multiclass neural network module to predict a multi-valued target knowing that neural networks of this type could be used in complex computer vision tasks, such as recognition of numbers or letters, classification of documents, of text (Questions) and for pattern recognition. In this sense classification, using neural networks is a supervised learning method. It, therefore, requires a tagged data set comprising a label column.

4 Proposed Method

Our proposed system is based on the four algorithms described in the second part of this article that follows supervised learning. The goal is to discover an underlying structure of the data. This algorithm requires a tagged data set. The E-Orientation Data Orientation Data Set is divided into two series, such as training data and test data. The classification performed by the algorithm used in our model is based on the knowledge acquired by the learning data during the learning process.

Our dataset was collected from the RIASEC test based on Holland's theory [32], [33], [34], it contains two columns namely:

Question: It contains questions and statements that measure either the occupations or the activities or abilities or the personality of the users.

Categories: we have four classes (labels) of categories namely:

1. Activity.
2. Occupations.
3. Abilities.
4. Personality.

In our research work on Guidance Classification, we used the Azure Machine Learning Studio [35] tool which is a collaborative drag-and-drop tool that we can use to create, test, and deploy predictive analytics solutions on our data. Machine Learning Studio publishes templates as a web of services that can be easily consumed

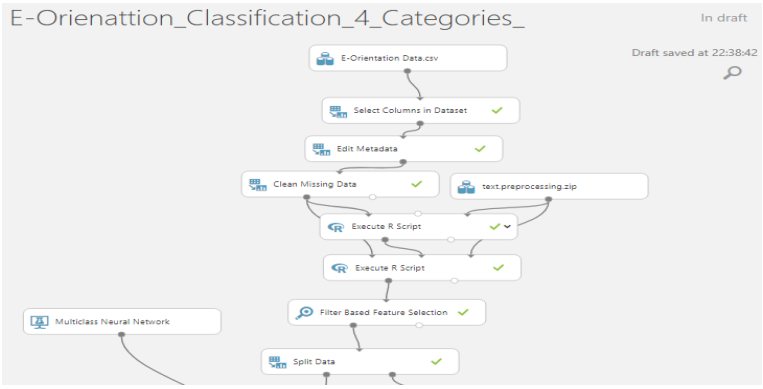
by custom applications. Machine Learning Studio is the meeting place of data science, predictive analytics, cloud resources, and our data.

5 Experiment and Results

The experimental steps described and illustrated in Fig.2.They are explained below:

a) **Importing the dataset***:* We import our dataset entitled "E-Orientation Data" that we collected from several websites from our local disk on Azure ML Studio to be used for the experiment and Category names that we have been used as a class tag or attribute to predict.
b) **Preprocessing and preparing the dataset***:* The dummy column headers have been replaced by meaningful column names by using the metadata editor. In addition, missing values have been cleared by deleting the entire line containing the missing value.
c) **Feature engineering***:* After the processing phase of the dataset, we will use the feature hashing module to convert the raw text of the questions into integers; and use the integer values as input entities of the model. Figure 3 represents our model.
d) **Split the data and parameter settings***:* We have divided the data of "E-Orientation Data" as 70% of the data for training and 30% for the test. Then for the Multiclass Neural Networks algorithm, we applied it with the default settings for model formation. The parameters have been set by using the "Tune model hyperparameters".
e) **The model:** each time We used one of these four algorithms
f) **Score and evaluate the model***:* The Evaluate model visualizes the results through the confusion matrix.

For the schema of our model, we can summarize it in the following figure knowing that for each algorithm we keep the same steps described in the figure except that we change the algorithm used.



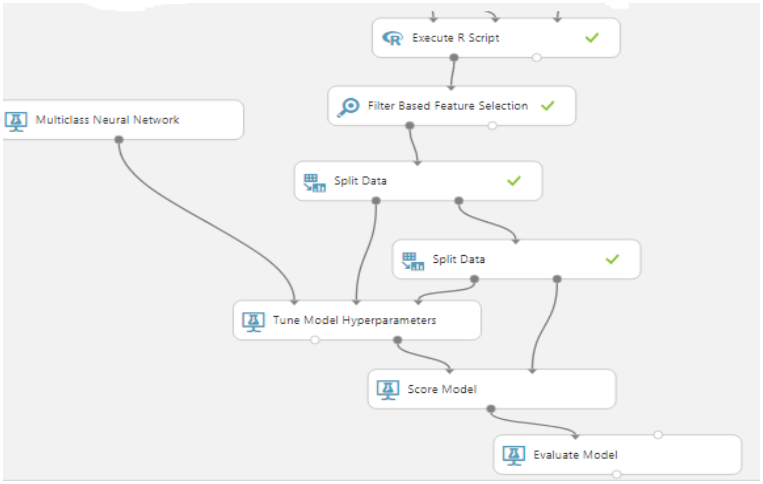


Fig. 2. Schema of model

Table 2. The metric values of the four Algorithms

Method	Overall accuracy	Average accuracy	Micro-averaged precision	Macro-averaged precision	Micro-averaged recall	Macro-averaged recall
Multiclass Decision Forest	0,75	0,875	0,75	0,824811	0,75	0,745726
Multiclass decision Jungle	0,75	0,875	0,75	0,824811	0,75	0,745726
Multiclass regression Logistic	0,795455	0,897727	0,795455	0,845833	0,795455	0,784188
Multiclass neural network	0,818182	0,909091	0,818182	0,8875	0,818182	0,811966

According to the results shown in this last table, we note that the results obtained by the Multiclass neural network algorithm are the best followed by the results of the Multiclass Regression Logistic algorithm and for the two algorithms we see that the results are the same., this shows us that the best algorithm to use is the Multiclass neural network algorithm [36].

For the matrix of confusion concerning the algorithm Multiclass decision forest, we have obtained the following in figure number 02.

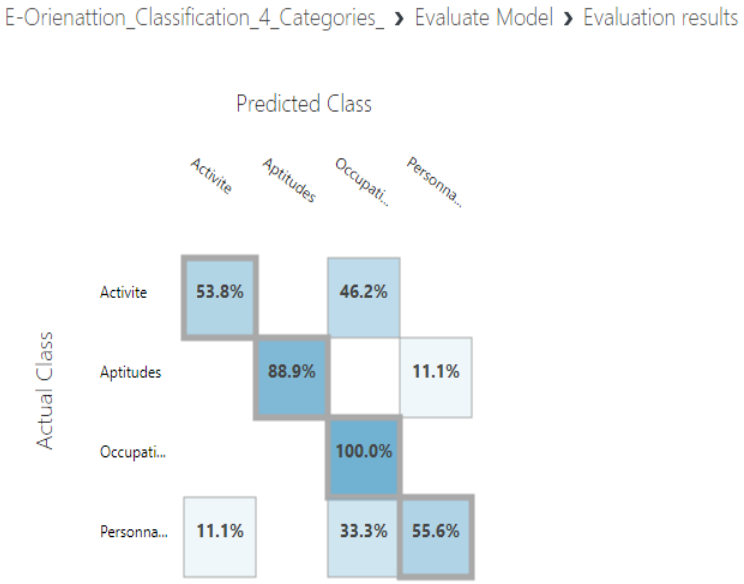


Fig. 3. Confusion Matrix of Multiclass Decision Forest

For the matrix of confusion concerning the algorithm Multiclass Decision Jungle, we have obtained the following in figure number 03.

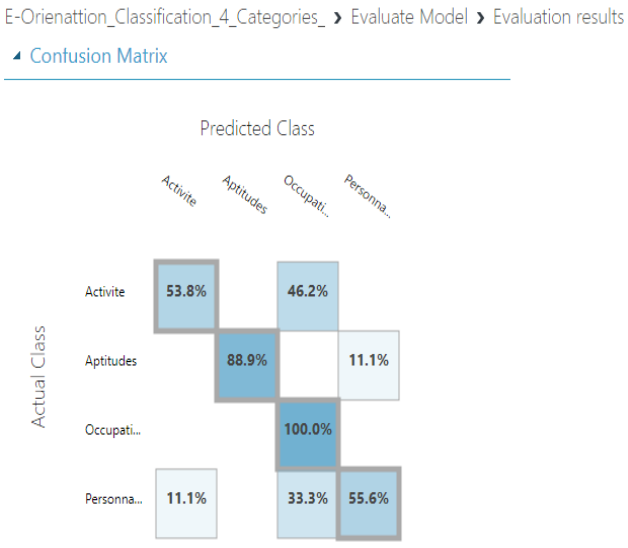


Fig. 4. Confusion Matrix of Multiclass Decision Jungle

For the matrix of confusion concerning the algorithm Multiclass Regression Logistic we have obtained the following in the figure number 04

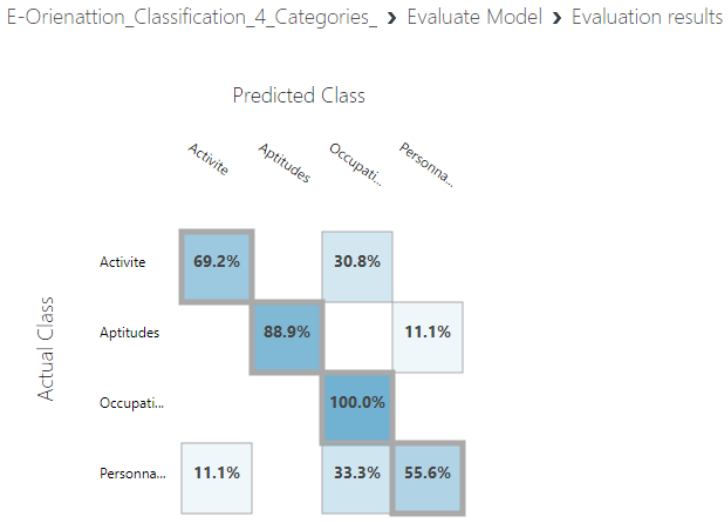


Fig. 5. Confusion Matrix of Multiclass Regression Logistic

For the matrix of confusion concerning the algorithm Multiclass Neural Network, we have obtained the following in figure number 05

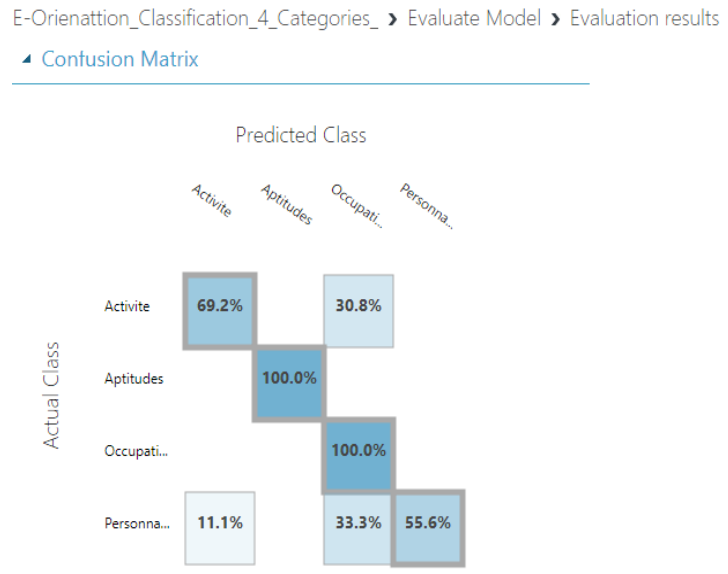


Fig. 6. Confusion Matrix of Multiclass Neural Network

6 Conclusion

In this article, we defined and applied the four machine learning algorithms used for text classification. We conclude that multi-class neural networks work better than the other three machine learning algorithms.

The Multiclass Neural Network algorithm used in our classification model of Academic and Professional Class Orientation Issues is implemented using Azure Machine Learning Studio. In fact, we found that the supervised method gives very good precision. This method can also be used to automatically generate academic and vocational orientation questionnaires by knowing the class of these proposed new questions in advance, and we can view this research question as a perspective. This automatic classification model using machine-learning algorithms can also help E-guidance researchers in the development process in this area.

As future work, we focus on the use of social network analysis, for example, using Twitter's sentiment analysis as a feature to determine the class of questions and interests of students and faculties of educational institutions. 'Education. The emergence of a new multi-label classification approach called BERT [37], the acronym for Bidirectional Encoder Representations from Transformers, is a language model (in) developed by Google in 2018. This method has significantly improved automatic language processing algorithms; the application of this method in our next work is an issue in order to compare the results obtained by the latter method with the results obtained by these four algorithms used in this research work. to develop a system of E-orientation is our goal knowing that online services (evaluation, learning) have shown their great effectiveness according to several researchers [38][39][40][41].

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The Total Network Capacity of Wireless Mesh Networks for IoT Applications

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Abstract—Computing and measuring the total capacity of a data network are a remarkably difficult problem. These metrics are directly linked to the available bandwidth to each wireless internet of things (IoT) device of the network. In this paper, the authors study the performance metrics associated with capacity traffic in multi-hop wireless mesh networks (WMNs). It is dedicated to Internet access, assuming a time division multiple access (TDMA). They focus simultaneously on three key operating metrics, the total network capacity (TNC), total application network capacity (TANC), and the Average message time (AMS). They also analyze how parameters such as forward error correction (FEC) and acknowledgments (ACK) affect the overall network capacity under different operating conditions. Theoretical network capacity for WMNs, in this paper, is explored to draw attention to the number of open research issues

Keywords—Wireless mesh network, network capacity, average message size, routing, network topology.

1 Introduction

WMNs are emerging as the more lucrative technology for determining wideband connectivity [1]. However, for ensuring the smooth operation and meeting the requirements of the applications, the applications require higher throughput; consequently, WMNs need a higher capacity for innovating solutions. The network capacity of a wireless mesh network (WMN) [2] implemented in the internet of things (IoT) is one of the significant criteria for quality of service.

With rapidly expanding numbers of WMNs [3] available for IoT [4] applications, developers need to understand how these networks differ concerning the use cases and expected performance.

Many parameters, such as error-Correcting Codes (ECC), message size transmitted, network topology, traffic pattern, network node density, number of channels used for each node, transmission power level, and node mobility, can influence the capacity of WMNs. The testing focused on device behavior and impact of AMS, FEC, and ACK [5] on network capacity, total IP network capacity, and total application network capacity. The network capacity can be enhanced by growing the number of gateways if they are sufficiently spaced from each other [6]. In effect, the network capacity is constrained by the activity inside a bottleneck zone around the gateway [6,7].

A significant surge in demand for total IP/application network capacity is invading the industrial internet of things (IIoT) [8] caused by an ascendant demand from IoT devices, and consumers with an exceptional and high ambition for real-time access to massive amounts of data services. Confront this insatiable consumer traffic demand; operators are obliged to enlarge network capacity. In the context of WMNs, network capacity (in bytes per second) can be considered as the intricate measurement of the maximum quantity of data that may be conveyed between network places over a network path. Because of the number of intertwined measurement variables and complicated scenarios, the actual network capacity metric is rarely found with a precise measure. In [9], the authors address the problem of calculating the transport capacity of WMNs destined to the internet. Capacity is also known as data rate or as throughput. Latterly, network coding technique has been used in wireless networks communication for improving network capacity, and it can also optimize the broadcast Strategy [10].

Network capacity planning is a critical approach of conveyable network architecture planning to guarantee an efficiency network has the increased capacity to meet future needs [11]. Analyses of the transmission capacity of multi-hop, wireless mesh networks regularly connect bounds on the maximal achievable data rate to spatial reuse constraints and MAC-layer impacts. In WMNs, all IoT nodes employ the identical physical channel (such as IEEE 802.11 [12] based ad hoc LANs). The total network capacity is certainly conditional on the coverage area of each wireless IoT node. Since a packet, transmission by a node efficiently precludes any transmissions, happening at about the same time, by neighboring IoT nodes (within its interference range).

Managing network capacity, to optimize performance depends on several essential parameters, namely: Rate at which handsets enter and leave a covered cell site area, average message size [13], average hops per path, modulation (type and rate), subscriber services, FEC and ACK, its parameters can also affect Trip Time Metric in multi-hop WMN as in [14]. Also, the number of nodes affects network capacity as in dense wireless sensor networks (DWSNs), which is one of the fundamental parameters such as in [15].

The IoT carriers are forced to grow network capacity to accommodate exploiters of IoT requests for high-bandwidth services. Nowadays, network capacity is required to handle increased IoT devices and supplementary services. For a similar reason, the total achievable network capacity is also a function of the IoT nodes density, which implicitly determines the average number of one-hop neighbors. In the paper [16], the authors analyze the capacity of wireless networks. With randomly located nodes con-

sidering two types of networks, arbitrary, and random networks. The authors of [17] expect the total capacity of wireless ad hoc networks, mainly; it studies 802.11 MAC interactions with ad hoc forwarding, their effect on network capacity

In this work, the authors analyze the network capacity of WMNs. It is assumed that each node is located in the middle of the region of the area, and it can transmit at bits per second over a shared wireless channel. Packets are sent from station to station in a multi-hop mode until they reach their single final destination (remote station). They can be buffered at intermediate stations while awaiting transmission. To simplify the tasks of the nodes, the medium access mode to be used is a TDMA, as applied in [13]. TDMA is a successful method for avoiding packet collisions. However, time slot distribution must be realized to use TDMA.

The paper presents wireless mesh networks and the effect of FEC and acknowledgments (ACKs) in IoT networks. It analyses and discusses network capacity, gives an overview of the system model, and presents contributions on some measurements and numerical results obtained for the described model.

1.1 Wireless mesh network

Wireless mesh network (WMN) is a wireless local area network (WLAN) using one or more decentralized IoT devices connection, include complete mesh topology or partial mesh topology. In a complete mesh topology, each network IoT node is connected directly to each of the other IoT nodes. In a partial mesh topology, some IoT nodes are connected to all the others, but others are only connected to those IoT nodes with which they interchange the most data. WMN is a promising wireless communication technology for various applications [18] to comply with specific requirements and uses.

In WMN, all IoT devices can access each other randomly and spontaneously, and each network IoT node can forward data to the next IoT node. The networking infrastructure is decentralized and simplified because each IoT node need only transmit as far as the next IoT node. Wireless mesh networking could permit users living in remote areas operating in rural neighborhoods to connect their networks for available IoT connectivity.

In wireless mesh-type networks, all IoT devices can access each other arbitrarily and spontaneously. WMNs can also accomplice polling or report-by-exception applications.

Each link between IoT nodes (and) could be noisy, so the information in the packets also needs to be encoded to verify and correct the errors. In this paper we analyze FEC, and ACK approaches, a class of time-diversity techniques, in the context of IoT network at the link and transport layers

1.2 Effect of FEC and acknowledgments (ACKs) in IoT network

FEC (Forward Error Correction) is an instrumental technique to understate IoT wireless channel weakness. The transmitter subjoins some redundant data into its messages. This redundancy permits the receiver to detect and correct the erroneous

packet. The improvement comes at the expense of the data transfer rate concerning each IoT devices.

$R_{data} = m \times r_{FEC}$, where R_{data} is the IoT device data rate, m is the modulation rate, and r_{FEC} = FEC ratio.

The above formula shows that the lower the FEC ratio, the better the ability of error correction and the lower the IoT device data rate.

ACK is a setting, which requires additional bandwidth to repeat corrupted frames. To announce that the packet was received correctly, each transmitted packet has to be acknowledged by the receiving IoT device, using the very short service packet (ACK). If ACK is not received, the IoT device will retransmit the packet depending on its set of new attempts. The authors in [19] analyze the effects of packet forwarding in Mesh Network on transmission performance.

When the IoT device has successfully received the transmitted packet, it no needs to reconstruct any dropped, lost, and missing packets at the receiver. Consequently, there is no requirement to receive ACK from the receiving IoT device, i.e., the packet is transmitted only once, and it is not re-iterated. It is noted that the acknowledgment/retransmission scheme is an integrated part of the radio protocol. It can work individually and separately of any new attempts at higher protocol levels (e.g., TCP or IoT devices application protocol).

2 Network Capacity

Starting from a given state of the network in which it is assumed that only TCP traffic is being processed. The network capacity is defined as the maximum TCP throughput that all IoT devices in their network could carry set. If each of them were to download as much as they can. Consider a WMN using a single radio channel shared among all routers that are assumed static. We distinguish the network capacity, defined as the maximum capacity of a link or network path to convey data from source (SCADA center node) in the network to the destination (remote station) via intermediate nodes.

In the context of the Internet of Things (IoT), a better network-wide capacity is necessary for providing a better quality of service to a more significant number of users.

In this paper, the TNC in bytes per second (includes IP packet overhead) is defined as the resulting number mentions to the maximum number in the ideally designed IoT node network. Notwithstanding, that figure can be solely completed when there is a considerable portion of the communication load among the IoT nodes (remotes) themselves.

When all control messages have ultimately to reach the SCADA center station over the same links employing the same radio-channel, any calculation of TNC loses its sense. This problem can be eliminated by adding additional channels or bypass dominant IoT devices using more radio hops. Usually, every network of devices using narrowband radios demands a capacity-aware layout.

Consider the network in Fig.1, which consists of three $(n=3)$ wireless routers coverages areas. Router 1 sends its packets to router 2, and, thus, the link $e_{1,2}$ has to be able to forward traffic. Router 2 starts forwarding its packets to router 3 via the link $e_{2,3}$ .Router 1 can exchange data with Router 2. Router 3 can also exchange information with Router 2. However, Router 1 and 3 cannot communicate with each other, but their signals can interfere at Router 2.

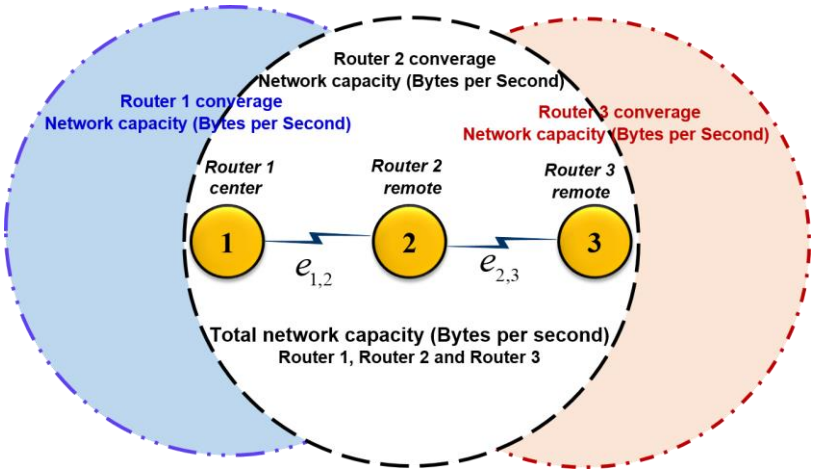

Fig. 1. The basic concept of the Total Network Capacity in wireless IoT devices.

Digital radio has developed ways in which more than one information conversation of the data center can be accommodated (multiplexed) inside the same physical radio channel. For achieving this, the TDMA method is used. It must be noted that in that case, TNC is dependent on the transmission range of each IoT node. So that the collisions cannot be excluded entirely; hence, a collision-solving system must be a complete part of the protocol in the radio channel.

Whenever the traffic increases over a specific limit, the number of collisions augments considerably, decreasing the instant network capacity well below normal situation.

3 System Model

In this paper, the fixed infrastructure of the WMN is represented by an acyclic directed graph $G=(V,E)$ with an IoT node-set $V=\{v_1,....,v_n\}$ representing mesh points and an edge set E . The directed edge connecting the IoT node v_i to the IoT node v_j is denoted by $e_{i,j}$.

It is assumed that all the IoT nodes are synchronized. Each edge $e_{i,j}$ has a capacity $C_{i,j}$ (bits/sec), meaning that a packet of L bits is transmitted in at least $L/C_{i,j}$ seconds. Consider that, for each link $e_{i,j}$, the maximum transmission delay of a packet of L bits is known and equal to $L/C_{i,j}+T_{i,j}$, where $T_{i,j}$ is the service delay over the links $e_{i,j}$.

Fig.2 shows the SCADA center and a chain of n IoT nodes, which respectively generates and forward traffic to the remote station (RS).

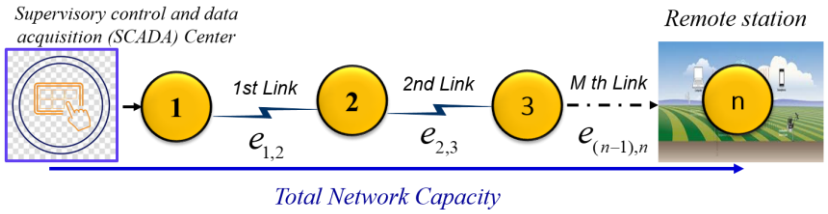

Fig. 2. Total Network Capacity with M links, a chain of n nodes generating and forwarding data to a remote station.

SCADA center sends control information to all IoT nodes. SCADA application typically uses a specific address for such control information. Along the paths of the highway system, one node is chosen per edge, which acts as a relay for the following node. The receiving IoT node 2 (directly connected to the IoT node 1 (one radio hop), converts such message to a customized IP broadcast and sends it to IoT node 3 over one IoT node 2 (two radio hops) respectively to all node's units within the network. Each link in the chain is constrained to send only when the other links in its vicinity are inactive. An objective to expand the system in WMNs is to stretch the coverage range of wireless IoT networks without resorting to the sacrifice of the channel capacity. Another aim is to provide non-line-of-sight (NLOS) connectivity among the IoT devices without direct line-of-sight (LOS) links. To meet these needs, the multi-hop paths are required [20]. Wireless mesh networking has become ideal for IoT, for smart car parking mobile application[21] , and it can be incorporated with different network capacities such as IEEE 802.11, 802.16, 802.15, etc.

Assume that each IoT node receives traffic to be forwarded to the RS and that each IoT node can only receive packets from its immediate neighbors. The traffic that has to be forwarded by each link is computed. It is clear from the picture that nodes closer to the RS have to forward more traffic than nodes farther. The RS is connected to the SCADA center through n IoT nodes, with the last one is considered as a remote station.

The packet must be completely received before being forwarded to the next IoT node. Consider D as a total delay for sending N packets crossing n nodes over M links (pipelining delay) that is given in the following form [22]:

D = Propagation delay + Transmission Delay + Pipelining delay

$$D = D_p + N * D_{TP} + (M-1) * D_{TP} \quad (1)$$

Where D_{TP} = transmission time of the packet. Each packet contains L bits of data and a header of size H bits with total packet size $L+H$ bits.

$D_p = \frac{d_{total}}{V_p}$, with d_{total} is the total distance between SCADA center and remote station and V_p is propagation speed over the specific medium.

The transmission of a message (control information) of S bits needs S/L packets; therefore, the time to transmit the message over M links is

$$D = \frac{d_{total}}{V_p} + \frac{S}{L}(\frac{L+H}{R}) + (M-1)(\frac{L+H}{R}) \quad (2)$$

where R is the data rate.

In this network, there is one source node (SCADA center) and one destination node (remote station). The source node does not have any incoming edges, and a destination node does not have any outgoing edges. SCADA center has a message for monitoring remote station system as in [19].

Consider that the total network capacity C_{TNC} is the relationship between the useful data trafficked, without any headers (IP, TCP, UDP,…), trafficked by all IoT devices and the total time takes them, so:

$$C_{TNC} = \frac{n \times L}{\sum_{i=1}^{n} T_i} \quad (3)$$

where n is the number of connected IoT devices and T_i is the average time, it takes each one to traffic L bytes of payload.

$$T_i = aSlotTime.\frac{(W_{\min}-1)}{2} + T_{data} + T_{ACK} \quad (4)$$

where $T_{data} + T_{ACK}$ is the total time it takes for a node i to download a full packet payload L.

Rewriting the equation (3):

$$C_{TNC} = \frac{1}{\frac{1}{n}\sum_{i=1}^{n} \frac{T_i}{L}} \quad (5)$$

Consider that C_i is the capacity that each IoT node obtained. Consider the case where only the one connected to the network which is equivalent to:

$$C_{TNC} = \frac{1}{\sum_{i=1}^{n} \frac{1}{n} \frac{1}{C_i}} \tag{6}$$

This last result represents the total network capacity assuming that all connected users are reporting as much as possible.

Total network capacity in bytes per second (includes IP packet overhead) is the resulting number refers to the maximum number in the optimally designed IoT devices network. While total application network capacity is total network capacity in bytes per second, but no IP packet overhead is included.

The following Table 1 lists the most critical measured parameter selected for the used topology.

Table 1. Setting Measurement Parameters.

Settings	Status /Mode /Type/Value
Average message size (bytes)	0-1500 (1460)
Processing time(msec)	20
Interface speed	ETH TCP/IP
Modulation	QAM
FEC, ACK	On /Off
Nodes number	9
The output power of each device	10 watts
aSlotTime	9-20 μs
Wmin	15
Wmax	1023
n	9

Usually, the maximum transmission unit (MTU), $MTU_{ethernet} = 1500 = 1460 + 20 + 20$ bytes corresponding to the payload, IP header, and TCP header respectively, consequently L takes the value of 1460 bytes.

Assuming there are no collisions, the average time of each countdown is $(W_{\min} - 1)/2$ time slots. For the first transmission, and after each successful transmission, the W value takes the $W_{\min}$ value. For each retransmission, this value W doubles until it reaches the $W_{\max}$ limit, the moment from which W stops growing. Then the plot discards a certain number of retransmissions. Also, it is assumed that there are only one SCADA center and one remote station in the network. Furthermore, every IoT node is capable of creating, receiving, or transmitting data over a communications channel. The topology illustrated in Fig.2 is respected for the simulation with $n = 9$.

4 Results

This section describes the results of the experiments. The presented measurements show how Total application network capacity (TANC) varies depending on the sever-

al Message sizes according to the modulation type (QAM). Various measurements are effectuated as a function of different values of AMS, without FEC/ACK or with FEC/ACK, respectively. Each device may support up to 1500 bytes of RF payload. In this case, the payload bitrate curve shape, depending upon the number of hops, AMS, and ACK/FEC, is illustrated in the figures that follow.

The Fig. 3 shows the results of TANC in bytes per second, (but no IP packet overhead is included) versus AMS with modulation type QAM.

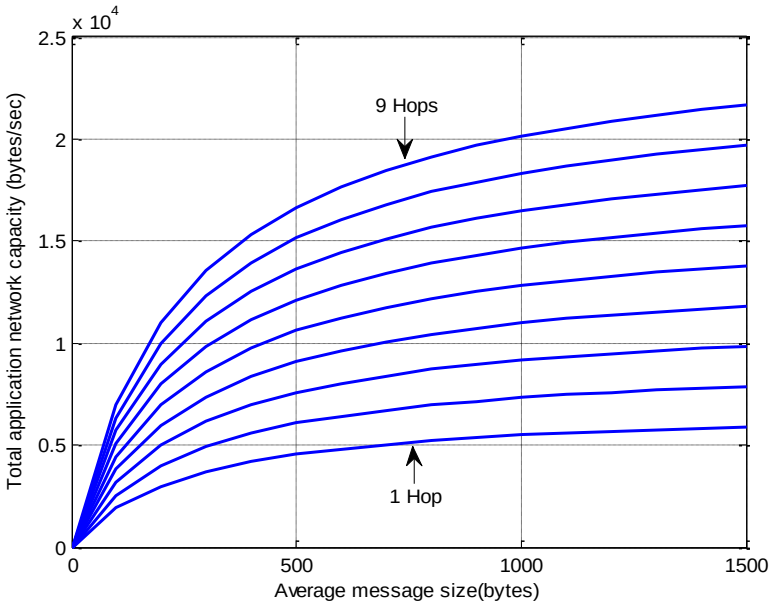

Fig. 3. TANC vs AMS: from n=1 hop to n=9 hops with identical retransmissions of Rayleigh channels using BPSK modulation Multi-Hop path.

According to the results shown in Fig. 3, it can be observed that the TANC increases considerably for the AMS values increase until 500 bytes, then increases slowly from 500 bytes to 1500 bytes. Additionally, one can see that the number of hops can also promote a significant increase in TANC.

The results illustrated in Fig.4 show the comparison between Total IP network capacity and Total application network capacity without any correction.

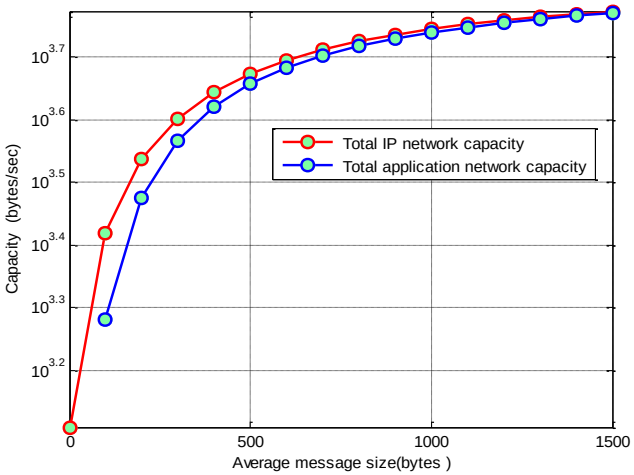

Fig. 4. Total IP network capacity and Total application network capacity without any correction.

It is noted that the total IP network capacity is high relative to the capacity total application network capacity, especially between zero and 600 bytes.

Fig.5 shows the effect of protocols (on network capacity), which can detect and recover the lost packets, either by data redundancy FEC=On or by retransmission ACK=ON.

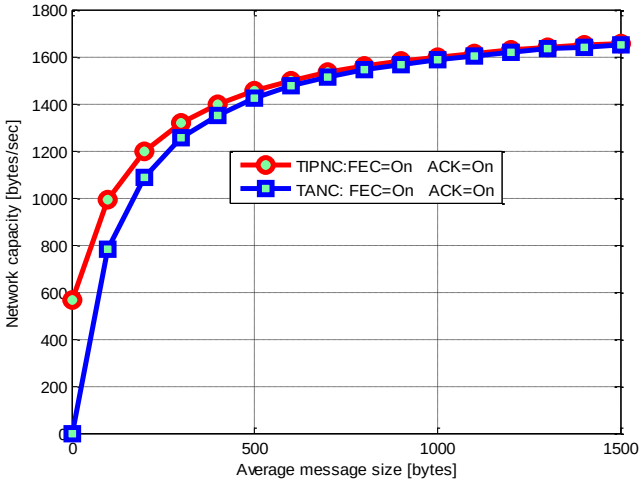

Fig. 5. Total IP network capacity and Total application network capacity without any correction.

The results in Fig.5 show that FEC, as well as ACK, have a significant effect on the network capacity. Additionally, our results reveal that packet loss recovery techniques promote a further decrease in network capacity.

The scenario is considered in Fig.2: direct transmission between the serial neighbor devices using nine routers. Fig. 6 shows the comparison of Total IP network capacity results obtained for different configurations of FEC and ACK by considering different fixed message sizes.

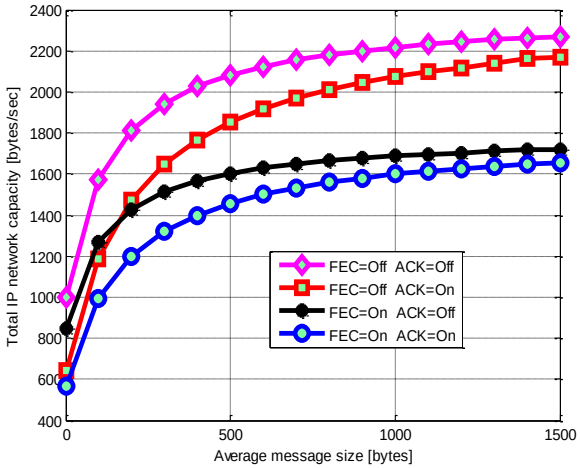

Fig. 6. Total IP network capacity vs. AMS using different configurations of FEC and ACK.

The results in Fig. 6 show that the using different average message sizes (bytes) in wireless networks, without FEC/ACK or with FEC/ACK respectively, has a significant effect on the Total IP network capacity. Additionally, the results reveal that the FEC decreases the total IP network capacity channel more than ACK.

In the same way, Fig.7 shows the comparison of total application network capacity results obtained for different configurations of FEC and ACK.

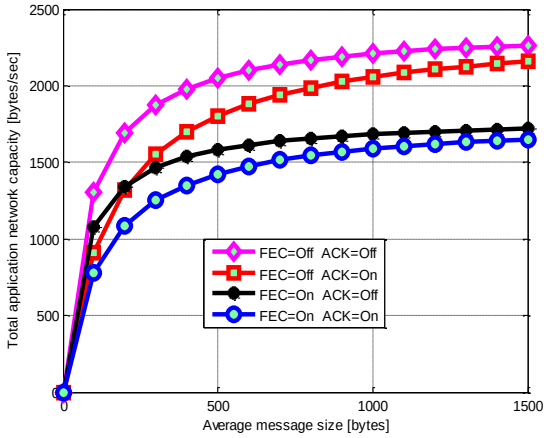

Fig. 7. Total application network capacity vs. AMS using different FEC/ACK configurations

The introduction of ACK increases the Total IP network capacity and total application network capacity more than the presence of FEC. Also, without any correction (FEC=ACK=0) only increases capacity but does not improve robustness to link failures, network congestion, and other problems of the wireless network communication.

Moreover, it can be noted that the results illustrate that the IP packet overhead promotes a further decrease in Total application network capacity. The use of FEC and ACK has the disadvantage of low network capacity.

To ensure the conformity of the experimental results, it convenient to compare them with the simulation result, as illustrated in Fig.8.

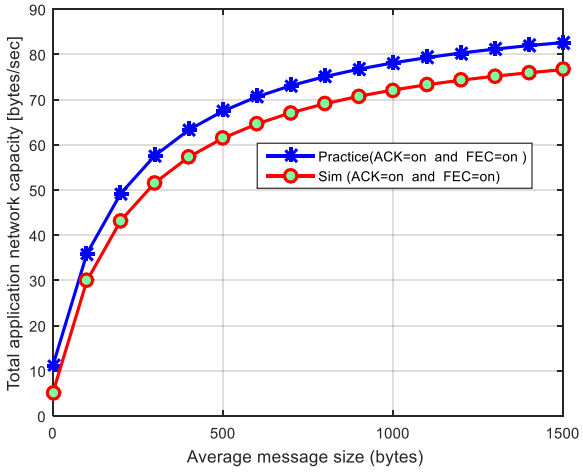

Fig. 8. Comparison between the simulation and measurement results of Total application network capacity vs. AMS using FEC and ACK.

In the case where ACK and FEC have become operational, the curve illustrated in Fig.8 shows that the experimental and simulation results are almost the same

5 Conclusion

In this paper, the authors focus on the analysis of TNC over a multi-hop, wireless network technologies, designed for the IoT, where all links share the same physical channel. Our analysis shows that it is often difficult to simultaneously improve both the TNC and the Error Correction Code (ECC). Number hops and average message size adversely affects the TNC. They analyze the case in which the noise in a given link is unrelated to the signals traveling over other links. In that case, the authors show, the problems of error correction and capacity network can be separated without limiting the capacity of the network as a whole.

Furthermore, the analysis of the results shows that the Error-correcting codes, such as FEC and ARQ, have two opposite effects on the efficiency of TNC in IoT networks with different lengths. Although ECC dramatically increases the reliability and performance of the overall system, the ECC also makes signals more robust; in contrast, it reduces the total network spare capacity. It also shows that there is a straightforward connection between TNC characteristics and observed packet size FEC and ACK. The more hops per path, the less overlap, and consequently, more capacity left for simultaneous transmissions from different IoT devices. That is the reason for higher capacity with more hops in the network, and it is the subject of the future work using a new performance algorithm.

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Antecedents That Influence the Intention to Use the Uber Mobile Application: Customer Perspectives in South Africa

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Abstract—In today's postmodern era there is a remarkable increase in the use of smartphones, GPS and the internet. This, in turn, has influenced businesses to adopt mobile commerce applications. The study sought to examine the impact of social influence, perceived convenience, facilitation conditions, and price value on the intention to the use the Uber application. A quantitative methodology was used and the research concentrated specifically on consumers located in the Johannesburg area. A self-administered data-gathering survey was used. In this research, Partial Least Squares-Structural Equation Modeling (PLS-SEM) was adopted as an approach to data analysis. The test results of the hypotheses showed that the intention to use the Uber application was substantially and positively affected by perceived convenience, facilitation conditions, social influence and price value. Ultimately, the shortcomings were discussed along with the guidelines and concluding remarks, based on the findings of this paper.

Keywords—Perceived convenience, facilitation conditions, social influence, price value on the intention to use the Uber application.

1 Introduction

In today's postmodern era, the prevalence of smart mobile devices is growing rapidly, reflecting a new generation of technical resources offering unparalleled access to content and creative usage opportunities [64]. In addition, mobile applications (apps) have changed the digital media landscape [66]. The understanding and rejuvenation of advanced technology has significantly changed consumers' needs and wishes [76].

Henceforth, [84] states that individuals have become accustomed to accepting data quickly and without constraints, wherever and whenever they need it. The spread of advanced technologies has made a difference in lifestyle, particularly for buyers' overall economic circumstances. This is particularly fundamental in the created world of sharing economies, where it is common for organisations to guide their business through online platforms. The sharing economy (defined as an economic system in which resources are exchanged among private individuals, free or at a cost, primarily through web methods [19]), depends on the rule that in a world with rare assets, it is frequently preferred to share rather than possess [57]. A good example – the car sharing company known as Uber – is a successful organisation within the sharing economy. Uber has been operating in South Africa for the last seven years, and has about 4000 drivers – more than 50% of whom operate in Gauteng [55, 26]. Uber operates in major provinces of South Africa, namely: Gauteng, the Western Cape, KwaZulu-Natal, and the Eastern Cape (as shown by [20]).

Uber has limited urban proximity, meaning it favors mostly urban residents over rural residents. The current development of on-demand, application-based ride services has sparked a debate about their role in urban transport [69]. However, [66] reported that in May 2015, Uber showed that it would try different payment methods to make it easy for people without a bank account or credit cards to use the service. The purpose is to build interest in Uber and to increase its market share. It has had the ability to expand the number of publicly visible Uber drivers, which has reduced the financial benefits enjoyed by traditional metered cabs. In South Africa, Uber has been designated drop off zones by malls and airports. South African organisations have exploited open doors connected to Uber. [31] states that the vehicle loan provider, Wesbank, has introduced a car rent option for Uber drivers as they saw an opportunity to benefit from the ride share app. This implies Uber drivers can rent cars to use for their business through Wesbank.

It is also important to note that – given the extensive theoretical contributions made by various marketing scholars regarding Uber's advent and rise in the South African context – there seems to be a scarcity of South African research studies highlighting the impact of perceived convenience, facilitation conditions, social influence and price value on the intention to use the Uber mobile application. Previous researchers in South Africa have examined transport network companies such as Uber in various contexts by focusing on: South Africans' experience with the application [31]; a study looking at whether public transport is failing poor South Africans [71]; the impact of Uber in the South African economy [47]; an examination of the use of Uber by public transport users [58]; and how Uber has changed the public transportation system in South Africa [23]. Based on the above findings, the researcher is persuaded that there is a dearth of studies examining factors influencing the decision to use the Johannesburg Uber Mobile App. So, this supports the need for the present empirical study.

The next section discusses the review of the literature, followed by the creation of the conceptual model, and the hypotheses. These are then followed by a discussion on the methodology guiding the analysis, before the study results, explanations, consequences, suggestions and conclusions are presented in the last sections of the paper

2 Empirical Literature

After a search on scholarly online databases and search engines, the literature was reviewed around the variables of this study. This section summarises literature on the research variables under investigation; namely perceived convenience, facilitating conditions, social influence, price value and intention to use Uber application.

2.1 Perceived convenience

As stated by [10], perceived convenience of the mobile application refers to the extent consumers think mobile applications are convenient for the efficient completion of a task. [56] further described perceived convenience as a degree of time, place and execution perceived when using the wireless network to complete a task. In their study entitled "perceived convenience in an extended technology acceptance model: mobile technology and English learning for college students". [11] described convenience perceived as the level of time, place and execution that one feels when engaging in mobile English learning. [27] emphasise that perceived convenience is a precedent affecting mobile technology.

2.2 Facilitating conditions

The term "facilitating conditions" refers to the degree to which a person feels that there is organizational and technical infrastructure to help use a program [65, 35]. Due to the availability and simplicity of conferring the demonstration, consumers would have standards that could easily be swayed, thereby forming more positive attitudes [45]. Moreover [12] and [45] noted that facilitation conditions had a positive impact on technology utilisation.

2.3 Social influence

[26] Suggested that social influence involves an endless cycle of exchanges that induce an individual's interest in representing themselves in a positive light to get approval from their social groups. Individuals tend to avoid anything that will attract disapproval from their social groups [27]. Generally, consumers tend to consider the views of their social groups before engaging in any behaviour including purchase behaviour [57]. It could be assumed that the social groups have an influence on the adoption of innovative products such as mobile applications.

2.4 Price value

The price value is defined as a cognitive comparison between the perceived benefits of mobile applications and the corresponding monetary costs in accordance with [51]. Individuals tend to be more price-sensitive compared to corporate clients [83]. Price

value could be seen as what consumers sacrifice to obtain whatever they desire. Therefore, the product or service is considered to have value when the cost of obtaining it is relatively less than what consumers get [83]. Therefore, price influences consumer decision making [38].

2.5 Intention to use the uber application

Three key variables influence intention, namely attitude, social norms, and perceived behavioural regulation [33, 50]. This concept represents an incentive for a person to perform a particular behaviour [3, 56, 71]. It may also be viewed as the behavioural determinant and the basis for potential buying decisions [1]. In addition, one should usually act in accordance with his or her intent, except in cases where there are unexpected obstacles, such as a lack of skills, or resources and opportunities [50]. [33] suggests that intention may be used as a behavioural indicator. The intention to use the mobile application was investigated by [72] and it was found that the intention to use it had an effect on the conduct of consumer product adoption.

3 Theoretical Model and Hypothesis Formulation

In Figure 1 the following theoretical model is provided based on the literature reviewed. The conceptual model does suggest that perceived convenience, social influence, facilitation conditions, and price value are the predictor variables, while intention to use the Uber application is the outcome application. The available literature highlights several validated works that inform the hypotheses. Such hypotheses emphasise various variable relationships in a way that allows empirical research. The hypotheses are used to allow logical analysis among variables of the relationships. Based on the empirical literature on perceived convenience, facilitation conditions, social influence, price value and intention to use the Uber application, four hypotheses (which are discussed in the following sections) were created.

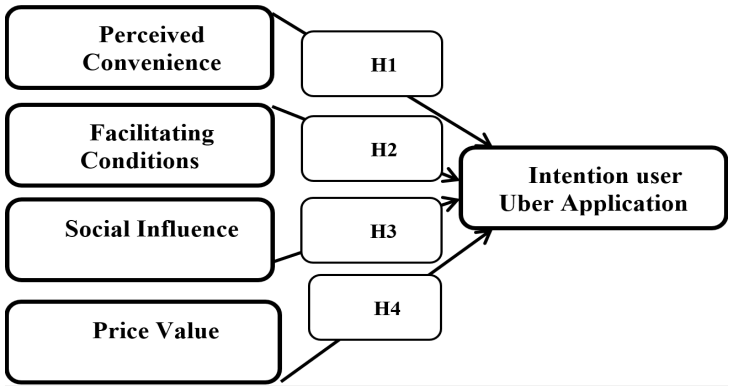

Fig. 1. Theoretical model and hypothesis formulation

3.1 Perceived convenience and intention to use the uber application

It is imperative to discuss the nexus between perceived convenience and intention to use the Uber application. Numerous studies – such as those conducted by [41] – have discovered that convenience is one of the most common factors affecting online consumer purchases. Consequently, online retailers or transportation network companies (such as Uber) need to simplify the online shopping process and try to make the application convenient for users [18]. In addition, [15] found that convenience also had a significant impact on the purpose of shopping online. Their findings coincide with the works of [40], who found positive relationships between perceived convenience and behavioural intention. Thus, this paper hypothesises that:

H1: Perceived convenience has a positive impact on intention to use the Uber application

3.2 Facilitation conditions and intention to use the uber application

A study conducted by [2] – which focuses on analysing factors influencing individuals' intentions to utilise social media and the empirical results from [2] showed that facilitation conditions have a positive impact on users' behaviour intention to use social media. In addition, [2]'s findings are in accord with the works of [43], who conducted a study on determinants of fashion mobile application adoption in Sweden. The findings of their research show that facilitation conditions influence fashion application adoption [51]. In addition, [5] explored the effect of fostering factors on the decision to implement e-learning. Results from the [5] study revealed that the decision to use e-learning apps was positively influenced by facilitation conditions. Consequently, we have formulated the following hypotheses:

H2: Facilitation conditions have a positive impact on intention to use the Uber application

3.3 Social influence and intention to use the uber application

According to [21] and [81], when it comes to social influence, consumers consider other people's opinions. These people can be referred to as reference groups – for instance, friends, family, peers etc. In a similar vein [2] state that if a person thinks the system is useful, then another person will think it is useful and wish to use the system. The study examining antecedents of e-payment adoption in a developing country (Indonesia), found that social influence positively influences consumer's intentions to use e-payment facilities [38]. In addition, [41] social influence has a strong influence on behavioural intentions. [44] and [69] point out that reference groups can should be taken into consideration by marketers when developing marketing communication campaigns. At times the influence of the social groups can disadvantage the organisation [67] when the social group members are not in favour of the organisation. The study on factors influencing Korean intentions to buy travel tickets online has found that friends influence the purchase decision [41]. Against this background, we propose the following hypothesis:

H3: Social Influence has a positive impact on intention to use the Uber application

3.4 Price value and intention to use the uber application

Price value can be classified as an important predictor of how likely it is that a consumer will intend to use the Uber application. Additionally, price is crucial for purchase decisions [36, 56]. Furthermore, [57] emphasised that price certainty changes the intention to utilise mobile shopping applications. In their study, [50] emphasised that, as long as the m-shopping fashion app is useful and enjoyable to use, people are willing to use m-shopping fashion apps without knowing the value of the price. Furthermore, in a conceptual study conducted by [84] (which focuses on deliberating on the variables impacting why consumers will choose Uber over traditional minibuses) established that the price of Uber services influences the intention to select Uber over traditional taxis [83]. Hence it can be hypothesised that:

H4: Price value has a positive impact on intention to use the Uber application

4 Research Design and Methodology

From the ontological perspective of objectivism of the research, this investigation pursues a positivistic framework as it seeks to discover a link between the variables presented for this analysis and uses measurement instruments for gathering data. Hence, a quantitative approach has been applied as it improves accuracy of findings by statistical analysis. The design was suitable for requesting the information required concerning perceived convenience, facilitation conditions, social influence, price value and intention to use the Uber application. The method also helps one to analyse the causal relationships to the constructs used in the research.

4.1 Sample and data gathering

A non-probability sampling approach was used in the present study to collect data from a conveniently chosen sample of 152 participants. [8] and [9] explain that data collection encompasses the physical or electronic collection of data from participants.

4.2 Questionnaire design

Based on preceding research, research scales were composed. Appropriate adjustments were made to fit the research context and the objective with a specific end target. The perceived convenience was measured using a scale of four items adapted from [73]. The facilitation conditions were assessed using a scale of three items adapted from [54]. Social influence was measured through the adaptation of [62] scale. A three-item instrument adapted from [82] was used to measure price value. Intention to use an Uber application was measured using a three-item instrument adapted from [82]. All the scales were measured on a five-point Likert-scale and the scale indicators were affixed to a strongly disagree 1) To strongly agree (5) Likert-scale continuum.

5 Ethical Consideration

Permission was provided by the research protocol graduate committee of Regenesys Business School, which is located within the Johannesburg metropolitan area. The researchers obtained an ethics clearance certificate from the established business school ethics committee before questionnaires were issued to the respondents. Ethical concern was unconditionally acknowledged and this study was performed in compliance with the ethical standards of academic research, which, among other things, protects the privacy and preferences of the respondents and guarantees the confidentiality of the information provided by the participants.

6 Data Analysis

In this analysis, the Social Sciences Statistical Packages (SPSS) were used to analyse data and to determine the causal relationships between the variables. Smart PLS SEM technique was deemed a precise technique to use. Smart PLS has emerged as an important approach to the study of casual models combining multiple constructs [14, 29, 30]. [30] Argue that Smart PLS is ideal for small-sample analysis. In addition, PLS modelling was carried out to fulfil the dual duty of first, generating relevant model requirements and, second, fitting the already defined model. PLS modelling enquires standardised latent variable scores, since the latter are linear combinations of the indicator variables [22]. The first step in implementing the PLS-SEM algorithm was therefore to normalise the indicator variables in order to have a mean of zero and a standard deviation of one. As a result, on the outer and inner models, the standardised model yielded factor loadings and path coefficients varying between zero and ±1 with values closer to one denoting power, respectively.

6.1 Demographical information of the sample

39.5% (n=60) of respondents were 60 years of age, followed closely by 30.3% (n=46) of respondents 52-59 years of age, 28.3% (n=43) of respondents 44-51 years of age. 2.0% (n=3) of the remaining respondents indicated that they were 36-43 years of age. The majority of respondents – 34.2% (n=52) – reported that their highest level of education was basic education. 33.6% (n=51) indicated they were degree holders. In addition, 27 % (n=41) revealed that their highest level of education was postgraduate or equivalent degrees. Moreover, 5.3% (n=8) of the respondents revealed that they possess diplomas. Moreover, 3.9% (n=6) of the respondents revealed that they were working as general workers. With regard to household income, the majority of respondents (45.4% [n=69]) reported having a household income below R5 000. This was followed by 44.1% (n=67) who indicated that they have a household income of R5 001-R10 000. The remainder of the participants (10.5% [n=16]) revealed that they have a household income between R10 001 and R15 000. Regarding the respondents ' preferred road transport', it can be pointed out that 55.3% (n=84) of the respondents reported that they were using Uber. This was then followed by those who indicated that they make use of

their personal cars (25.7 percent [n=39]). In addition, 11.8% (n=18) revealed that they make use of ordinary taxis. Furthermore, 4.6% (n=7) of the respondents revealed that they use buses, while 2.6% (n=4) of the respondents specified other types of road of transport, for instance, motorbikes and bicycles.

7 Correlation Analysis

Correlation was used to explain the intensity of the relation between the variables proposed [36]. The matrix of correlation between the variables was taken up and provided in Table 1.

Table 1. Correlations matrix between constructs

Research Construct	Facilitating Conditions	Intention to use an Uber Application	Perceived Convenience	Price Value	Social Influence
Facilitating Conditions	1				
Intention to use an Uber Application	0.675	1			
Perceived Convenience	0.653	0.693	1		
Price Value	0.573	0.611	0.696	1	
Social Influence	0.541	0.624	0.577	0.342	1
Note: **Correlation is significant at the 0.01 level (2 tailed)					

8 Reliability Analysis

The reliability results are presented in Table 2.

Table 2. Accuracy analysis statistics

Research constructs	Cronbach's alpha test		CR	AVE	Factor loading
	Item-total	*Alpha value*			
Perceived Convenience					
PC1	0.594	0.733	0.829	0.549	0.671
PC2	0.601				0.714
PC3	0.613				0.734
PC4	0.624				0.835
Facilitating Conditions					
FC1	0.691	0.868	0.910	0.717	0.837
FC2	0.693				0.887
FC3	0.711				0.863
FC4	0.713				0.797
Social Influence					
SI1	0.708	0.712	0.830	0.619	0.742

SI2	0.712				0.825
S13	0.694				0.791
Price Value					
PV1	0.751				0.758
PV2	0.755	0.738	0.852	0.657	0.848
PV3	0.757				0.824
Intention to Use the Uber Application					
IUUA1	0.696				0.809
IUUA2	0.714	0.790	0.827	0.619	0.882
IUUA3	0.721				0.651
Note: CR=composite reliability; AVE=average variance extracted; a significance level p<0.001; b significance level p<0.01; c significance level p<0.05.					

The calculation of three different methods, namely Cronbach's alpha reliability test (Cronbach α), the composite reliability test (CR) and the average variance extracted (AVE) tests, tested the construction reliability of the study measures.

9 Discriminant Validity

The study used the matrix of correlation and the average variance extracted (AVE) to assess discriminant validity of the research instruments.

9.1 Correlation matrix between constructs

This section conducted an examination of the similarities between the constructs. The statistics on correlation tests were used to explain the presence of a relationship between the constructs, as well as the association's direction and strength [57]. In order to analyse the relationship between perceived ease, enabling circumstances, social influence, price value and the intention to use an Uber, non-parametric correlations were computed. As shown in Table 1, the co-efficient of inter-correlation between latent constructs was less than 1.0, which is consistent with recommendations [60] and [11] and thus provides evidence of discriminatory validity. A strong positive linear association between facilitating conditions and the intention to use Uber at r=0.675, p<0.01 meaning point, suggests that facilitating conditions affects the intention to use Uber. Additionally, the relationship between perceived convenience and intention to use the Uber application is positive at r=0.693p<0.01, and the table shows the positive relationship between price value and intention to use a Uber application at r=0.611, p<0.01. Moreover, table 1 also shows that there is a positive relationship between the social influence and the purpose of using the Uber application at r=0.624, p<0.01.

10 Partial Least Squares Structural Equation Modelling Approach

The researchers will quantify the goodness of fit measures with Smart PLS, since it provides the R^2 values for the dependent variable. In the current study, intention to use the Uber application is the dependent variable. The fit-goodness has been determined using a global fit-goodness approach [76]. Hence, for this analysis, the following section shows how goodness of fit was measured.

10.1 Assessment of the goodness of fit

Overall, R^2 in Figure 2 indicates that the model explains 63.2% of the variance in the endogenous variable for perceived convenience, facilitation conditions, social influence and price value. The global goodness-of-fit statistics for the research model were calculated using the equation, according to formulae given by [77]:

$$\text{Goodness of fit} = 2\sqrt{(\text{average of all AVEs values} * \text{average of all R2})}$$

$$= 2\sqrt{2.67*0.13}$$

$$= 0.59$$

Where AVE represents the average for the study variables of all AVE values and R^2 represents the average of all R^2 values in the complete path model. The estimated global goodness of fit (GoF) is 0.59, which exceeds the GoF>0.36 threshold indicated by [86]. So, this study concludes that the overall fit of the research model is good.

10.2 Path model results

Figure 2 displays the PLS estimation results for the structural model as well as the loadings of items for the study constructs.

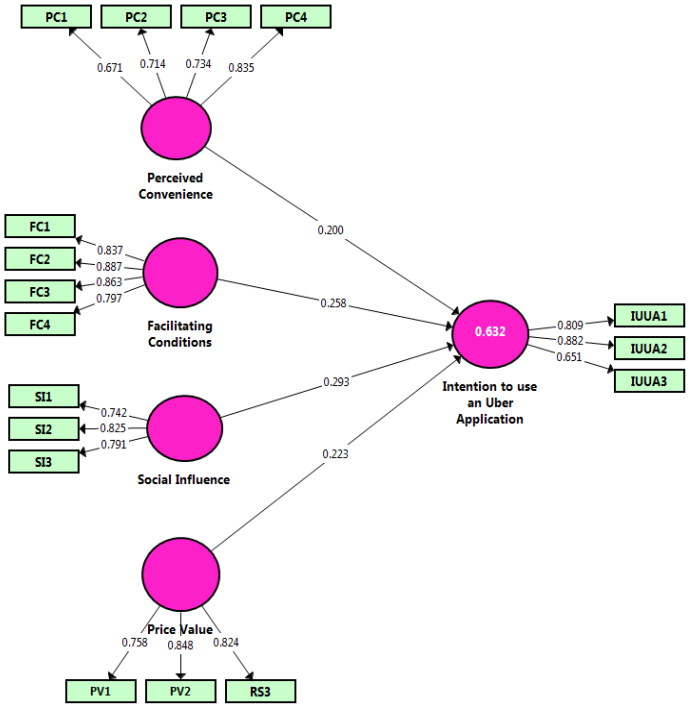

Fig. 2. Path modelling and factor loading results

Table 3. Results of structural equation model analysis

Path	Hypothesis	Path coefficients (β)	T- Statistics	Decision
PC → IUUA	H1(+)	0.200	2.457	Positive and significant
FC → IUUA	H2(+)	0.258	3.669	Positive and significant
SI → IUUA	H3(+)	0.293	3.761	Positive and significant
PV → IUUA	H4 (+)	0.223	3.417	Positive and significant

11 Testing of the Hypothesis: A Discussion of the Smart PLS Results

According to [52], data analysis has several benefits, but the most significant is to help organise the findings into micro parts from data gathering sources and macro problem segments. To properly complete this analysis, it is important to evaluate the collected data in order to test the hypotheses proposed. The path coefficient values and t-values obtained from the bootstrapping algorithm have been tested for hypothesis. According to [73] Path coefficients (β) and t-statistics are used for a model to test the relationship between the independent variables and the dependent variable. In other words, how the data endorse the hypothesised model [61] is analysed by the path coefficient and the t-values.

11.1 Outcome of hypotheses testing: H1: Perceived convenience have a positive impact on intention to use an uber application

In Figure 2 and Table 3 it is clear that H1, the relationship between perceived convenience (PC) and the intention to use an Uber application (IUUA), is confirmed by the outcome of the analysis (β=0.200) and is relevant at t-statistics value of 2.457. Relationship strength is demonstrated by a coefficient of value of 0.200. This means that perceived convenience directly affects the intention of the user to use an Uber application in a substantive, significant manner. This finding has ample support from previous empirical research studies, such as [40] which found positive relationships between perceived convenience and behavioural intent. These results are similar to the results of [68], which is that consumers feel the sharing economy is making life more convenient for individuals. The results also agree with [87], which found that convenience affected mobile application adoption. The research [7] conducted on hotel and peer-to-peer accommodation user expectations showed that perceived comfort affects the decision to use the Airbnb mobile application.

11.2 Outcome of hypotheses testing: H2: Facilitating conditions have a positive impact on intention to use the uber application

In Figure 2 and Table 3, it can be found that H2, the relationship between facilitation conditions and the intention to use the Uber application, is confirmed by the outcome of the path coefficient value of (β=0.258), and is significant as indicated by a t-statistics value of 3.669. Relationship strength is demonstrated by a coefficient of 0.258. This means that facilitation conditions directly affect the intention to use the Uber application in a constructive, significant manner. The findings of this study also authenticate the presence of a positive relation between the facilitation conditions and the intention to use the Uber application. The results obtained in the present study are not without empirical support either. This result is supported by past literature, which found that facilitating conditions allow consumers to participate in virtual communities [65]. The results of a study evaluating the requirements for boundary-spanning activity in governance networks [80] showed that facilitating conditions affected the adoption of network systems among government employees. Similarly, [79] found that facilitating conditions play a major role in the implementation of inter-organisational seaport information systems. [34]'s study established a relationship between Uber users facilitating the conditions and behavioural intentions. Generally, facilitating conditions influences the adoption of new technology [46].

11.3 Outcome of hypotheses testing: H3: Social influence has a positive impact on intention to use an uber application

In Figure 2 and Table 3 it is shown that H4 strongly supports the relationship between social influence and intention to use the Uber application. The t-statistics are 3.761. Relationship strength is demonstrated by the coefficient of direction of 0.293. This finding suggests that the price value has a direct positive influence on the purpose of using

the Uber service. In this study, empirical evidence was also found suggesting a positive association between social influences, which positively impact the decision to use the Uber application. This is in line with [38], who discovered that social influence has a positive effect on electronic payment system intention. Moreover, [43] found that social influence (subjective norms, social factors, and image) has a positive impact on behavioural intent to participate on the website of a political party. The finding coincides with previous results by [61], which confirmed that social influence favourably and significantly affected the restaurants' desire to use mobile apps. The study conducted by [78] on adoption of mobile diet applications revealed that the most important determinant of the intent to use is social influence. Furthermore, [78] it has been identified that social influence often exerts a positive moderating impact on the relationship between hedonic interest and sharing economy purpose.

11.4 Outcome of hypotheses testing: H4: Price value has a positive impact on intention to use an uber application

Figure 2 and Table 3 show that H4 significantly supports the relation between price value and intention to use the Uber application. The t-statistic value is 3.417. Relationship strength is demonstrated by the coefficient of direction of 0.223. This finding suggests that the price value has a direct positive impact on the purpose of using an Uber car. The study also showed that the price value associated with using the Uber application has been good. This results supported [83]'s empirical study, which focuses on the factors influencing the decision of the consumer to choose an Uber over a traditional taxi. Their paper suggests that perceived price affects customers' intention to use Uber service as opposed to taxi services in tourism destinations [83].

12 Recommendations

This research established a close link between perceived convenience and intention to use the Uber mobile application. Therefore. Uber, as a service provider, should strive to enhance the convenience of using the Uber mobile application to influence people to use their application and speed up the adoption of their mobile application. Organisations engaged in a sharing economy should emphasise convenience during system development and ensure that they communicate convenience as a unique selling proposition of their mobile application. With South Africa having the most expensive data in Africa [37], and South Africans spending approximately 25% of their monthly salary on data [25], Uber could introduce free WiFi hot spots in big cities such as Port Elizabeth, Johannesburg, Durban and Cape Town, which could be used by Uber users to request trips and be made accessible to data-deprived riders. It can be recommended that managers of the Uber application should strive to improve the simplicity and interactivity of the application so that consumers can view the application as convenient.

Given the strong connection between facilitating conditions and intention to use an Uber application (0.258), managers should focus on providing resources and conditions that facilitate the use of the Uber mobile application. In addition, in order to improve

its performance, continuous efforts should be made to improve the design and functionality of the Uber mobile application. Uber apps can be designed to provide resourceful, helpful and up-to-date information, as well as digital content that meets individual needs or capabilities. In addition to providing convenience passengers, the Uber application's system implementation should also aim to provide and promote functionality and continuance intention. Uber should consider developing a mobile application that is user-friendly to riders with disabilities. They should consider adding features that help enable non-verbal communication between the Uber driver-partner and the rider. Uber should also introduce wheelchair accessible vehicles in South Africa to cater for riders with mobility disabilities. Driver-partners who will be picking up disabled individuals will need training on how to interact and assist their clients. This can be Uber's competitive advantage in South Africa.

Following the rising penetration of South Africa's mobile marketing, improvements in customer use of digital media and technology are key to understanding digital marketing trends [23]. Uber marketing managers therefore need to invest in innovative technologies in order to gain a competitive advantage in the mobile marketing industry – this creates value for customers using Uber taxis as their mode of transportation. Uber's South African marketers will give priority to developing new strategies to keep up with the technology developments as the mobile platform evolves on a regular basis [23, 52]. Innovation includes marketing campaigns featuring new or cutting-edge strategies or innovations to promote a company or product [21]. Marketers need to ensure that their marketing campaigns exploit new, innovative as well as imaginative implementation of proven technology [52]. A good strategy involving technology that can be applied to young consumers is location-based; any marketing campaign uses location-based services as the primary anchor of the campaign to communicate with customers and deliver highly relevant, personalised messages at a time and place when consumers are most likely to act on them [62]. As a result of the open-ended nature of technology, marketers are posed with no limits in the generation of their ideas.

Uber managers can provide incentives or bonus points to existing users of the Uber mobile application to recommend the use of Uber to their friends. In doing so, current Uber mobile application users will persuade their peers to follow their example. This will give impetus to social influence, culminating in improved behavioural intention towards the use of the Uber mobile application.

13 Limitations and Opportunities for Future Research

As with all studies, this analysis, which opens up doors for further research, has several limitations. The first constraint is the current research background. The research background for this analysis is a developing country (South Africa). If applied to other contexts, the analysis may produce different results. However, the population of the study was small, as it included only consumers within Johannesburg, a city in South Africa. That restricts the probability of generalising the findings to include all South African consumers. Therefore, the study results may only be applicable to customers in

the Johannesburg region. Secondly, the sample size was set to 152 consumers. For future research, a larger sample size could be used, and may produce more interesting results. Third, the research model's predictability could have been improved if more independent variables were included in the research model to affect the behavioural intent to use the Uber application. Therefore, this study focused only on four antecedents, viewed as perceived convenience, facilitating conditions, social influence and price value. Digital marketing academics should examine other factors instrumental in stimulating the intention to use the Uber application, such as perceived risk, the need for reputation and the immediate need for service. Eventually, since this research focuses on the decision to use the Uber application, potential researchers can extend the analysis by researching the determinants of the Uber application's actual usage.

14 Conclusion

Keywords were included in the current study, key questions and theoretical objectives were identified, and a literature review was undertaken to gain an overview or a deeper understanding of the concepts. The research does authenticate that variables such as perceived convenience, social influence, facilitating conditions, and price value are influential in enhancing the intention of using Uber. This research explores theoretical and organisational consequences. In theory, this study makes substantial advances in marketing strategy theory and consumer behaviour by methodologically examining the interplay between perceived convenience, social influence, facilitating conditions and price value on the decision to use the Uber application. Therefore, this study makes a significant contribution to the body of knowledge. In practical terms, perceived convenience, facilitating conditions, social influence and price value were exerted as having a favourable effect on the intention to adopt the Uber application; improvements in each of these four factors may stimulate intention to use the Uber application among consumers in Johannesburg, which is located in the Gauteng province of South Africa. Perceived value can be taken into account by making sure customers can afford the Uber fares. Uber's marketing professionals can use the demographic profile of the customers who participated in this survey to learn consumers ' affordability in terms of household income. Doing these things in a more refined manner will certainly lead to the Uber application being of good service.

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Development of ICMLS Version 2 (Integrated Communication and Mobile Laboratory Simulator) To Improve 4.0 Century Industry Skills in Vocational Schools

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Abstract—The focus of this research was to develop an "ICMLS (Integrated Communication Mobile Laboratory Simulator)" in the form of mobile laboratories innovations for vocational teachers and students of Computer and Network Engineering. This was produced through the development of R & D with support from industrial partners in order to make all teachers and students in Vocational High School, West Java experiences the quality of the product. The prototype developed accommodated all practical activities for class X to XII in one integrated package for server and client functions. This research was conducted for 2 years, and in the first year, 2018, ICMLS version 1.0 was produced and 2.0 will be produced in the second year. This product can improve the competence of Vocational students in Computer and Network Engineering Study Programs to compete in the 4.0 Industrial Revolution Era which is more characterized by Artificial Intelligence and Big Data. This was evident from the increase in the average competency test of students from 85.13 to 85.53 produced from the lowest initial skill average of 77.9 to the highest of 89.4.

Keywords—ICMLS, Mobile Laboratory, Vocational High School, Computer Network Engineering.

1 Introduction

There is intense competition in the labor market through the world, especially for local, national, and international employees, furthermore, Indonesia and other developing countries also face this challenge [1]. However, it has been discovered that one of the best ways of producing prospective workers is education. Since the period of the Dual System Education curriculum in the 80s, formal education has been contributing greatly to the integration of the skills and knowledge needed by industries into the programs of vocational school education. Moreover, despite the technological advancement of this era, this system is expected to maintain its role in preparing students for the labor market. However, there are differently effective,

inexpensive and innovative learning models that can be equally implemented to make this happen. One of these is the rapid development of laboratory requirements through different technologies. This is supported by the findings of [2] that the high-speed development of technologies and its consequent effect on education has greatly influenced both traditional teaching and learning mode. However, there is a high financial implication in developing laboratory with a number of software and hardware tools, especially in the areas of Information and Communication Technology such as Computer Engineering and Networking, Multimedia, and others. In Indonesia, there are many SMKs with limited facilities and infrastructure such as special laboratories for practicum. This shows that vocational learning still lacks basic amenities needed for adequate knowledge impartation, therefore, several efforts have been made by researchers, practitioners, industries, and schools towards the establishment of the innovative, cheap and reliable modern laboratory.

Integrated Communication Mobile Laboratory Simulator (ICMLS) is a mobile laboratory developed for practical activities of vocational students in Computer and Network Engineering. It can be applied in many activities such as:

1. Assembling personal computers.
2. Installing a basic operating system.
3. Applying safety, occupational health and the environment (K3LH).
4. Implementing peripheral functions and PC installation.
5. Diagnosing problems with PC operation and peripherals.
6. Repairing and/or resetting PC Systems.
7. Conducting PC maintenance.
8. Installing GUI operating system and CLI.
9. Installing software.
10. Installing local network devices (LAN).
11. Diagnosing problems with operation of PCs connected to the network.
12. Repairing and/or re-setting network connections.
13. Installing GUI and text-based network operating systems.
14. Installing broad-based network devices (WAN).
15. Making the design of network security system.
16. Repairing and/or re-setting broad-based network (WAN) connections.
17. Administration of servers in the network.
18. Designing and analyzing WANs.
19. Designing a web database for server content [3].

There are various challenges observed in the development of 19 laboratories needed in teaching the courses highlighted above through ICMLS version 1.0. Therefore, version 2.0 was produced to be an innovative model of laboratory automation systems with some peripheral functions aimed at achieving effective and efficient learning experience. It was created using mechanical technology, an electronic microcontroller such as the automatic motion monitor screen system, mini BTS automatic motion system, keyboard, remote control, and server computer operating systems.

Therefore, the purpose of this study was to provide innovative, modern, user-friendly, mobile, practical and inexpensive laboratories in order to effectively prepare vocational graduates of Computer and Network Engineering Study Programs in Indonesia for facing the 4.0. era [4]. Based on these objectives, this research specifically produced a number of concrete solutions that can be immediately applied in schools and they include: 1) Mobile laboratory prototype model. 2) Design and development of prototype Mobile Laboratory which is able to maximally integrate infrastructures owned by Vocational Schools. 3) An affordable ICMLS manufacturing model of Mobile Laboratory to meet the needs of these schools 4) Forms of ICMLS implementation to facilitate practicum and competency test in all Referral Vocational Schools in each Province.

The ICMLS model found a number of ideas from Educational Technology experts that can be used in learning practical simulation media in computer science and engineering. Likewise, it was practically tested for efficiency in conducting competency tests and speed for students in mastering all components of client and server computers. Its design and architecture also utilize transparent materials and open spaces with consideration for occupational health and safety. From the Human-Computer Interaction perspective, the program has the ability to diagnose a student's weaknesses while studying computer and network techniques. The ICMLS integrated hardware, software, and environ ware functions through the automatic and quick control of user's brainwave, in this case for teacher and students. Therefore, through the implementation of the findings of this program, students, teachers, schools, education technology experts, computer science and engineering professionals, and the informatics industry can be made to understand information technology. Practically, it allows the computer industry to have a clear idea of the product to be produced with respect to users' need.

2 Literature Review

2.1 Mobile laboratory

This term is defined from several previous research findings where it was termed 'Mobile Technology' to be an object with a moving technological character. It is lightweight, moveable and can be used for the benefit of learning anytime and anywhere without having to be in a physical laboratory [5] and also applied for competency test of students. Whereas [6] asserted that the mobile laboratory is "a place for conducting experiments, investigations, etc. related to physics, chemistry, biology or other fields of science".

Based on the above understanding, the mobile laboratory can be interpreted as a set of tools that can be used anywhere because of its movable nature to conduct research or experiments. In this research, it was constructed from the combination of software, hardware, ergonomic systems, architecture, multimedia, mechanic automatics, artificial intelligence, and remote control. This technology has an animated software response for use in learning supported by animated pedagogical agents (APA) as

stated by [7]. It was particularly designed for the learning process and vocational competency test of computer and network engineering study programs. This is in accordance with the opinion of [8] that the evaluation configuration module must provide an effective user interface in assessing the competency of clients.

The development of the mobile laboratory was founded on the assumption that innovative learning requires the preparation of modern education media. In support of this, [9] emphasized that media education should lead to positive, critical and differentiated attitudes in making active choices and offer knowledge in three areas including: 1) Communication or communication-mediating means 2) Reception and 3) Content analysis.

2.2 Computer and network engineering

The study of computer and network engineering in high and vocational schools or equivalent level is part of the competency needing in studying information and communication technology [10]. It includes algorithms and computer programming, computer and network assembly, as well as software operation. It also requires an understanding of electrical engineering and computer science in order to develop and integrate software and hardware. In communication science, the study of computer networks is closely related to Computer-Mediated Communication (CMC). [11] explained that the same technology is afforded at different levels of visibility and influenced by behaviors relating to availability to colleagues, engagement in communication, and forms of knowledge sharing.

2.3 Computer and network devices

Recently, computer technology has experienced very rapid development in various fields. Its influence is frequently seen in every working system innovation and automation that has been developed to support human work. The education sector requires the application of this technology; however, a number of researches have been conducted to ensure students, teachers and other stakeholders in the sector enjoy the benefit of technological advancements.

Through the study of different architectures, networking and the combination of automation, both software, and hardware, a new product was produced to reduce the costs of procurement and maintenance of effective learning. The results of this innovation produced an Electronic Simulator which can help students to learn computer network science. Furthermore, it can be said to be an example of [9]'s Computer-Mediated Communication used in supporting practical learning activities without worrying about obstacles faced by users, especially the availability of laboratory space. Therefore, it can be established that modern computer, communication, multimedia, and network technologies are aimed at improving human communication and the amount of information currently processed by the new media is far from the traditional media [10].

It is expected that the 'ICMLS Model' would be developed by integrating a number of hardware devices into one multifunctional tool, ranging from learning

communication media, basic training courses to networking analysis competency tests. Therefore, the model developed in this research consists of several computer components and networks which are integrated into one mobile laboratory package and named 'ICMLS'. However, it is important to note the basic components of personal computers, and they include:

a) Processor, the brain of a computer, and a conceptual processor consisting of Arithmetic Logical Unit (ALU), Control Unit (CU) and Memory Unit (MU).
b) Motherboard/Mainboard, the main part of a computer.
c) Memory/RAM (Random Access Memory).
d) Hard Disk, functions as a place to store data.
e) Optic Drive (Optical Disk Drive) such as CD-ROM Drive, CD Writer, Combo Drive, DVD-ROM Drive and DVD Writer.
f) Keyboard.
g) Mouse.
h) Expansion Card (VGA Card, Sound Card, LAN Card) used in expanding the PC's capabilities;
i) Modem, which means Modulator and Demodulator.
j) Monitor, a device to display output from a computer in form of an image (visual).
k) The printer, a peripheral device used for issuing output through prints on paper.
l) A scanner, a tool used in scanning images from a paper.
m) External storage media, functions like a hard disk, except that it is not fixed;
n) Casing and Power Supply (PSU), which are two important components in assembling a PC.

2.4 Industrial revolution version 4.0

The ability of humans to think and learn as observed in the 21st-century will soon be renewed through the introduction of various disruptive innovations [12]. This will help in creating new markets by disrupting or destroying the existing ones through the replacement of old technologies with the latest. It also helps in developing products or services in an unpredictable manner [9]. This theory was popularized in the globalization era after innovators experienced several dilemmas in producing good products. However, several researchers in education has developed different innovations different from previous ones by combining disruptive innovations with scientific products of Educational Technology [13]. ICMLS is a prototype of the products from these efforts and it was conceptually designed to integrate learning resource requirements with some subjects needed by vocational students, especially in the Department of Computer and Network Engineering. Therefore, this prototype is expected to be a response to the submission of [15] about using disruptive innovation to improve schools as reported in [14].

This study shows that a number of educational development products in the Industrial Revolution 4.0 era are produced from a combination of 21st century competencies and individual human abilities through Hinger Order Thinking Skills

such as: 1) Digital Economy, 2) Big Data, 3) Artificial Intelligence, Robotics (Ministry of Research Technology and Higher Education, Indonesia, 2018).

The application of these competencies in equipping vocational students is observed in the innovative product of this research.

The practicality of ICMLS is established on its ability to either get learning materials from the teacher or in the class. In this case, it involves the migration of laboratory space functions into mobile devices through the use of previous research efforts on virtual classroom [1], networking mobile games [16], education mobile world class [17], and the concept of mobile-based learning.

In order to make the ICMLS model broader through the addition of different types of subjects, several previous concepts and findings from world experts were consulted. Therefore, the design and implementation of this model with the support of government and industries would make it become one of the best ways of solving the problems of competency in all computer and network engineering study programs of all vocational schools in Indonesia. It will also make the graduates of these schools possess the capability to compete with others from Southeast Asia and other parts of the world.

3 Research Method

The research was conducted for over two years and divided into two periods with the first in 2018 and second, 2019. The University of Education in Indonesia, Bordeaux University, IPI, and Nusantara Vocational High School Laboratories were used for the research with support from the Republic of Indonesia Ministry of Education and Culture. Research and Development method as proposed by [18] was used. This involved ten steps and they include

1. Research and information collection
2. Planning
3. Preliminary product development
4. Preliminary field testing
5. Main product revision
6. Main field testing
7. Operational product revision
8. Operational field testing
9. Final product revision
10. Dissemination and implementation.

During the test revision phase, 8 Vocational Schools in the East Priangan region of West Java Indonesia were purposively sampled. After the production of a proven ICMLS prototype, there was a collaboration with "PT. INTI" to produce commercially.

4 Result and Discussion

4.1 Mobile laboratory prototype and the requirements of computer and network engineering study programs vocational practice

The results from field studies showed that obtaining laboratory requirements for students in the Computer and Network Engineering Study Program of SMK is quite complex. The 8 Vocational Schools assessed were SMK Negeri 4 Tasikmalaya; MJPS 1 Tasikmalaya Vocational School; SMK Negeri 1 Kedawung Cirebon; SMK Negeri 1 Lemahabang Cirebon; Majalengka YPIB Vocational School; Muhammadiyah Majalengka Vocational School; SMK Negeri 3 Kuningan and SMK Negeri 1 Soreang. They reported that the model to be developed must be able to work digitally, electronically, and online in order to bridge the interaction process between server and client as emphasized by [19] in their research entitled "Online discussion compensates for suboptimal timing of supportive information presented in a digitally supported learning environment".

The prototype designed was aimed at improving the ability of the students to learn more interactively in changing conditions and places. This is in agreement with the results from [20] that mobile technologies could be used to improve performance. The model became a medium of communication between teachers and students, as well as the computer system itself. The teachers may use it to communicate with the server computer systems and students with the client computer systems or partners. These are meant to improve the learning process through the laboratory practicum. Furthermore, [21] revealed that the model is a useful way of communicating and learning. This finding is established on three major elements of communication which are senders, receivers and the media. Therefore, the model was designed in such a way that it met the requirements of the intended users and this was found to be in line with the opinions of [22] in Blended learning - State of the Nation. Figure 1 shows that illustration of the ICMLS products produced during the research process.

Fig. 1. Initial Portable ICMLS Model Prototype

The initial prototype had many challenges such as mobility and lack of automatic character. Furthermore, the next phase was designed, revised and developed to be cheap, easy, mobile and have a mini tower that integrates both software and hardware in order to meet up with the requirements of a laboratory. Figure 2 shows the sketch version of ICMLS 1.0 developed during the research.

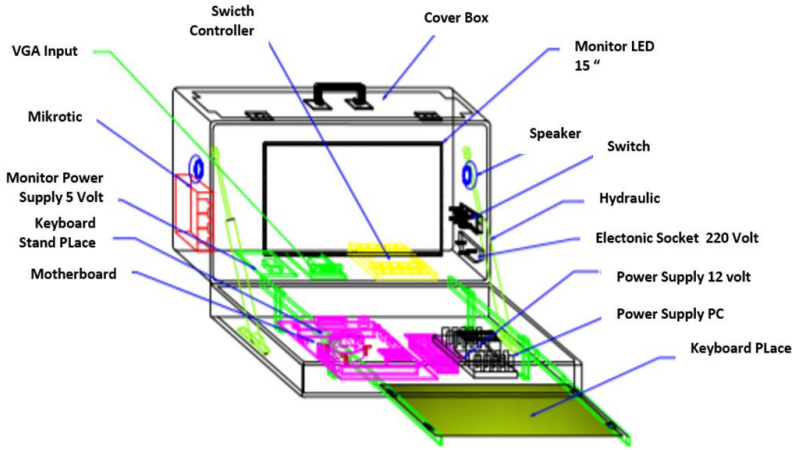

Fig. 2. Sketch of ICMLS version 1.0 prototype for Server

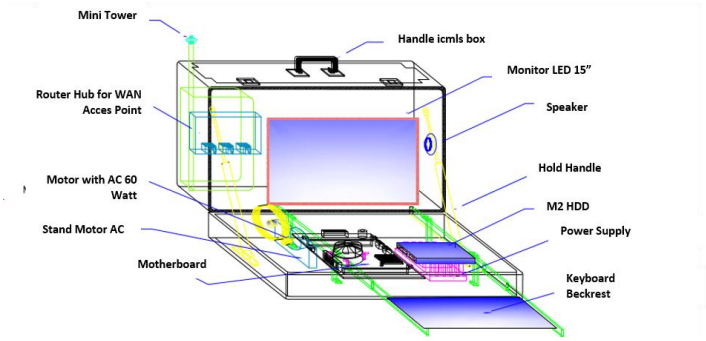

Fig. 3. Sketch of ICMLS version 1.0 prototype for Client

4.2 Design of mobile laboratories prototype with the ability to optimally integrate the Vocational Schools infrastructure

The results of a field study conducted on 10 Vocational Schools in West Java region revealed that there is a need for appropriate hardware and software for the model to be effectively implemented by student users [23]. It was also reported that the schools' infrastructures may also serve as an obstacle to several practical activities. However, the learning resources made available by ICMLS mobile laboratories have embodied the idea of [24] about the introduction of open

educational resources (OER) in acquiring knowledge. Therefore, the initial hypothetical design was produced based on the results of previous researches [21].

The product was developed through the following steps

1. Preparation and measurement of all components needed for both the client and server.
2. Design of component design.
3. Design and construction of an automated system using a remote system.
4. Provision of mobile box design suitable for construction design.
5. Assembly of components and remote systems according to their functions;
6. Checking the communication automatically between the client checkbox and the server.
7. Analysis of box's ergonomic suitability during communication.
8. Analysis of communication stability between client and server boxes while communicating.
9. Communication trials between the two when simulating *Computer and Network Engineering Study Programs* materials.
10. Review and improvement of components compatibility, ergonomic, and speed of automation system between clients and servers.
11. Hardware box stability test when opened for a number of clients and server systems.
12. Analysis of shocks and movements that disturb stability between components in the ICMLS box server and client.

The users of this product, both teachers and students, focus on their existence through the application of the concept of Human Communication Interaction [9]. It also gives them the opportunity of communicating various learning activities in depth. The general steps involved in assembling ICMLS are as shown in Figure 4.

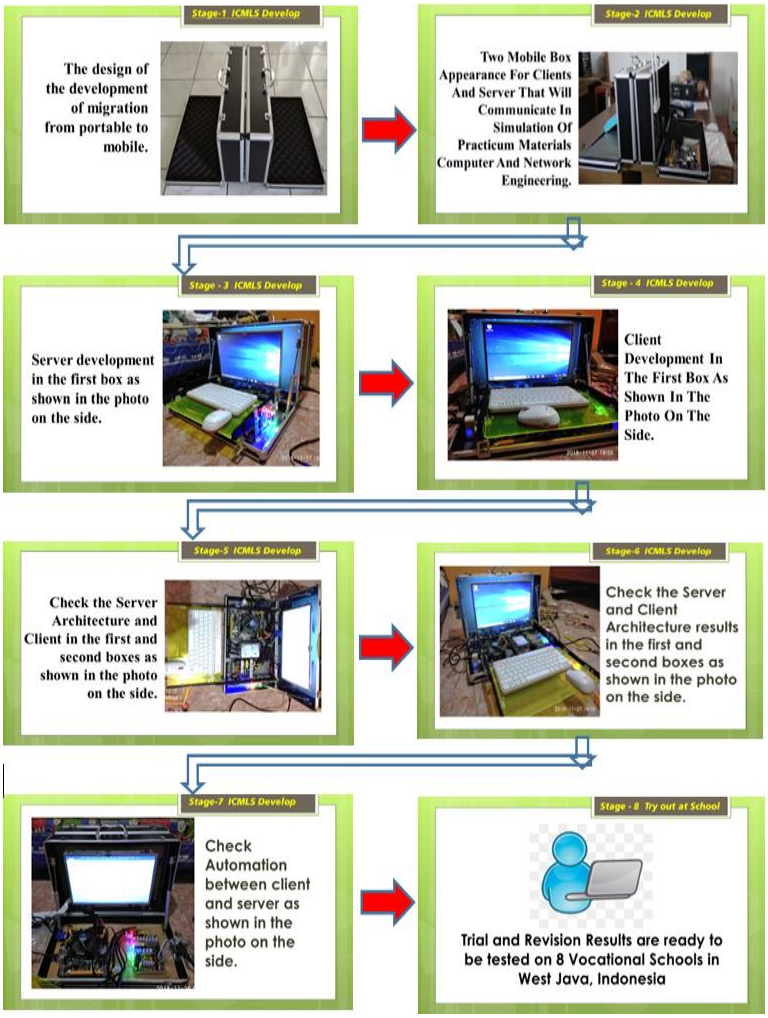

Fig. 4. ICMLS Development Stages

The ICMLS was made ready for use after the hardware and software have been adequately developed. It was tested by using it to practice a number of subject matter and competency test in the *Computer and Network Engineering Study Programs* department of 8 selected vocational schools. The ICMLS server and Client prototypes are presented in Figure 5.

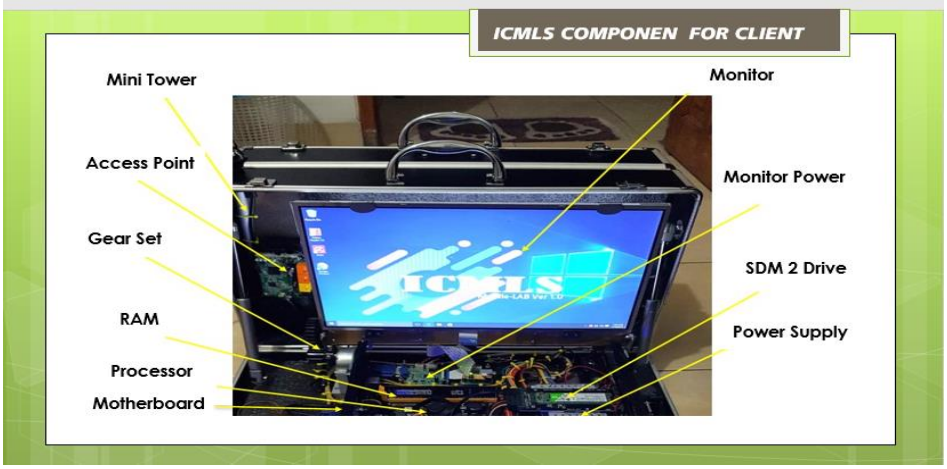

Fig. 5. Architecture of ICMLS for Client.

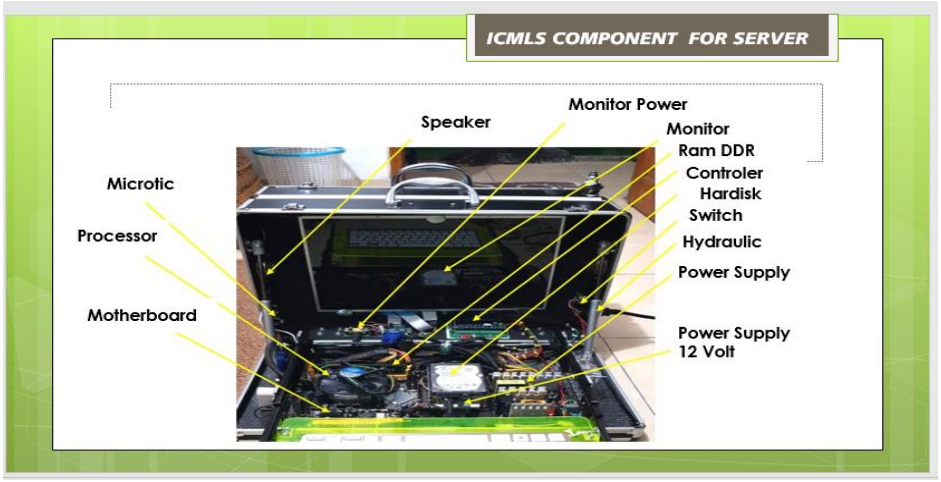

Fig. 6. Architecture of ICMLS for Server

The result of the tests conducted is shown in Figure 7.

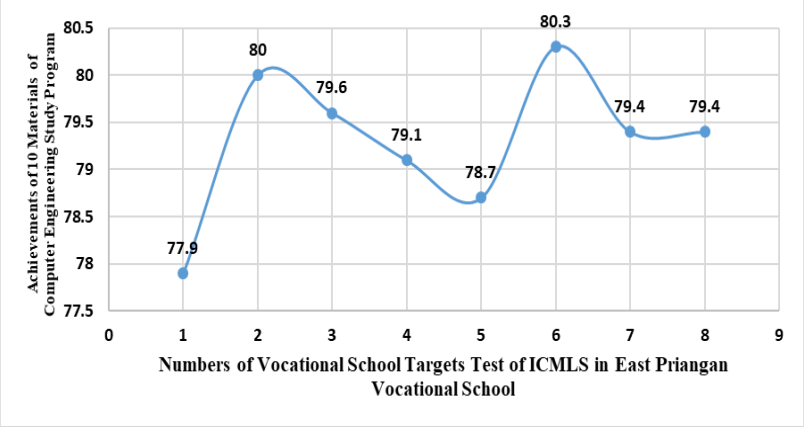

Fig. 7. Condition of Achievement Value 8 Vocational School of Computer Engineering Study Program

Table 1. List of *Computer and Network Engineering Study Programs* Practical Materials by Using ICMLS

NO	Computer and Network Engineering Study Programs of Vocational Schools in Indonesia
1	Assembling a Personal Computer
2	Installing the Basic Operating System
3	Applying Safety, Occupational Health and the Environment (K3LH)
4	Implement peripheral functions and PC installation
5	Diagnosing problems with PC operation and peripherals
6	Repair and/or reset PC System
7	Performing PC Maintenance
8	Installing the GUI Operating System and CLI
9	Installing Software
10	Installing a Local Network Device (LAN)

The results obtained from field testing were continuously improved to rectify the weaknesses observed before the products would be commercially produced [25]. It is important to state that one of the industries that are interested in producing the product is PT. INTI in Bandung West Java, Indonesia.

4.3 Designing ICMLS manufacturing process as a mobile laboratory for commercial production

In order to produce ICMLS commercially, the research team partnered with the Product Production and Commercialization Sector of PT. INTI to design a flowchart as shown in Figure.7. Therefore, the target is to produce ICMLS generation 2.0 model, which is more complete with respect to architecture, automation, mobility, as well as voice conditions by 2019-2020 to facilitate its users.

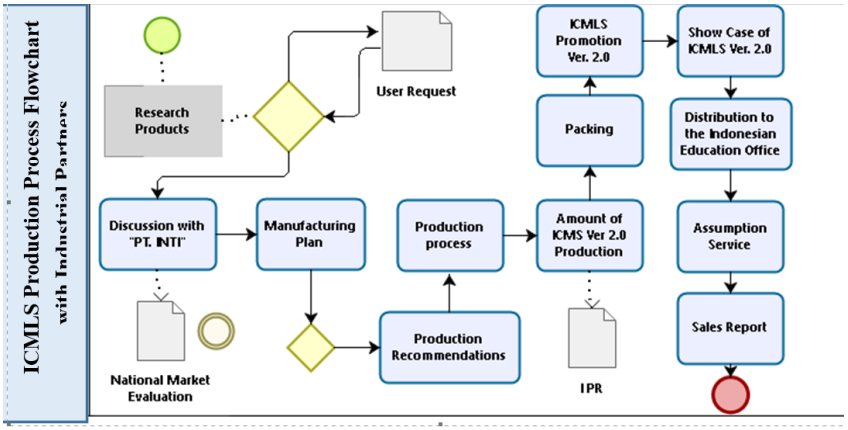

Fig. 8. ICMLS National Version Affordable Flow Manufacturing Version 2.0 by the Research Team with PT. INTI

The process shows that advancement will meet the needs of quality and inexpensive laboratories. Furthermore, ICMLS can also improve the quality of learning in *Computer and Network Engineering Study Programs* of Vocational Schools in developing countries throughout the world

4.4 Implementing ICMLS to facilitate vocational school students' competencies

The program was implemented through coordination with the head of the *Computer and Network Engineering Study Programs* and the homeroom teacher in charge of students' practical. Furthermore, the teacher communicated with the head of the laboratory about the use of ICMLS for students according to the practice schedule. This was conducted in groups after the students have learned the manuals, characteristics and work systems of ICMLS. Moreover, the application of Computer-assisted instruction (CAI) is a relatively new practice in most African countries, where only the minority of population only access information and communication technology (ICT) [26]. This made it possible to integrate the manual materials into the ICMLS software in order to encourage interactive communication and learning. Students can make use of the materials to understand simulations involved with the use of the product.

The product was designed to be user-friendly in creating interactive communication for the teachers controlling the servers as well as the students who serve as the clients. ICMLS was equipped with voice condition as a response to the explanations of [7]. The product also makes it possible to simulate and demonstrate all education courses in the Computer and Network Engineering Study Programs for learning purposes. However, there is a need to manage the quantitative access rights of users by modifying the IP address of ICMLS version 1.0 products from 192. 168.

1.1 for Access Points and 192.168.88 for Microtics. The Wi-Fi access address is: 1) Icmls_client. 2) Icmls mobile laboratory as explained by [6].

These can communicate in a limited manner through mini towers or antennas installed on the server section while the development of automatic movement instead of open-closed client screen was controlled by the level of remote-control system developed based on research conducted by [6].

Several technologies are implemented in the design and production phase such that: Access control system used VVS technology through control remoter. 2)

Mechanical technology used mini hydraulics on the opening part of the Client and server. 3) The open layer client technology made use of an electromagnetic wave amplifier system to trigger the mechanical technology of the client screen. This was supported by the power generated from the Dynamo AC Motor that was sending power to the gearshift. 4) Conventional technology for wheels. 5) Engineering design for the ICMLS Box. While standard network application system, windows installation, office, MS Access, and other applications made up the software technology used in developing ICMLS version 1.0.

The implementation of the product equipped with a manual guide for the targeted teachers and students was analyzed. It was discovered that the inclusion of the manual can result in effective and efficient use of the ICMLS product. Other aspects of OSH such as the required power voltage, safe placement of the products, and level of accuracy for convenience are expected to be adhered to by the users

During the practicum, the ICMLS was placed in front of the class for students to pay attention to the communication process between the client and the server. However, [27] advocated building on the competencies that students bring to the learning situation. In accordance with this, ICMLS was designed to support students' efforts in achieving their competence. Furthermore, in learning subjects such as computer design and installation, students were allowed to move towards the product and make use of it in turn. The ICMLS can also be placed in the middle of the classroom where all students surround it and observe how it is being used by their teachers and students or amongst them.

The simulation of ICMLS version 1.0 developed next was packaged in measurable learning videos in order to gradually measure the interaction between the results of the observation of the practice process through the engineering of the learning environment in a usually large and wide laboratory. There was also a large set of instructional design theories that prescribe how these types of environments should be designed [28].

5 Conclusion and Recommendations

5.1 Conclusion

ICMLS is a digital learning prototype developed in the form of a mobile laboratory that can be used to improve competence in practical activities of Computer and Network Engineering Study Programs students. The use of this tool is easier, more

concise and fun with a variety of futuristic and innovative features to increase student learning motivation. Furthermore, schools are no longer burdened with having to add space to a laboratory because ICML is portable, light and easy to carry. The result of the analysis conducted on 8 Vocational Schools showed a very significant increase in the average competency skill of students and all the score achievements.

5.2 Recommendations

The application of ICMLS provided several advantages and competencies for vocational students of *Computer and Network Engineering Program*. Therefore, it is recommended that the next product should focus on software, networking, and other features in order to fulfill the instructional design model [29]. This should be further implemented until the product can be easily and cheaply fabricated with the help of industrial partners.

6. Acknowledgement

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Development of Online Teachers-Student Consultation Application

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Abstract—This research presents the development of online teachers-students consultation application. A need assessment was conducted to determine what subjects, which activities, respondents' preference and attitude towards face-to-face and online consultation. These gathered data were treated using the descriptive method while the v-model was used during the development cycle. Java, web services and several web technologies installed in computer with i3 processor, 4GB DDR III RAM and with 500GB hard drive were the tools utilized in the application. Essentially, the study was able to develop an alternative to the traditional way of meeting the students physically to address academic difficulties, curricular and extra-curricular needs.

Keywords—Consultation application, online meet ups, addressing academic difficulties, virtual meeting.

1 Introduction

Allocating an extra time and responsiveness to students beyond classroom hour are two of the qualities a great teacher embodies. The presence of a mentor to lend a helping hand no matter how small or big the scale is, is sealed to them by virtue of their profession. Thus, scheduling consultation hour is deemed necessary. It is a value-added service beyond classrooms hour for the students to seek assistance on academic, curricular and extra-curricular related concerns. The aim of consultation is to help students cope with lessons, intensify learning and complete the needed task beyond classroom hours or as simple as sharing to their teachers what bothers them. This

usually lasts for an hour depending on the degree to which they need help and the expertise of the teachers on the topic at hand.

A sudden changed in behavior, a more engaged students on his academics, motivated individuals and increase score to test and quizzes are examples of desirable outcomes teachers expect among students to measure effectiveness of this program. These outcomes could be used to determine which lessons need to be strengthened as part of an intervention program plan to low performing students. The exact reason why schools and universities are implementing it as an academic service and in compliance with the rules and regulations of different accrediting bodies [1].

The technical feasibility of online consultation is possible because of the proliferation of software and hardware that supports it. With 4.77 billion estimated number of mobile users this 2017, [2] reveals that adapting to technology requires less skills and effort. In fact, there are schools that allow electronic communication to address students' needs aside from meeting them face-to-face [3]. Certainly, in the prevalence of modern technology, process automation is deemed necessary.

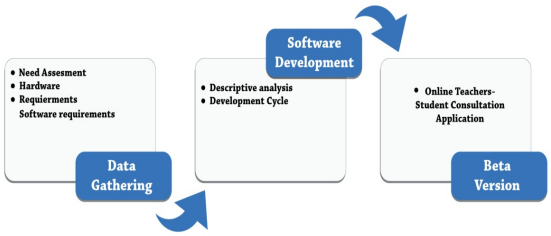
This study did not compare nor identify strengths and limitations of which is better with or without technology. The developed Online Teachers-Student Consultation Application simply presents as an alternative in conducting consultation hours based on the student needs and the scope to which process could be automated.

2 Objectives of the Study

The objective of this study is to design and develop an online consultation application for students to assist them in their academic difficulties. It also seeks to:

1. Determine students' preferences on where the developed software be applied
2. Automate a process to present an alternative way on addressing students need on academic, curricular and extra-curricular.
3. Provide needed data that may be used for faculty rating, curriculum evaluation and intervention programs.

3 Methodology



In order to come up with the On-line Teachers Student Consultation Application, a need assessment using the triangulation approach was conducted in Centro Escolar

University 2nd semester of School Year 2016-2017. To get the needed sample, out of 500 students from various courses, the researcher used Sloven's formula with 5% degree of error. The stratified random sampling technique was used in the selection of the respondents to ensure that the number of respondents from different campuses is proportional to the overall population. The researcher used two hundred twenty-two (222) students to answer the survey questionnaire and selected a few students for interview to verify and confirm data needed for this study. However, the researcher used random sampling to get the fifty (50) respondents. To determine internal consistency and reliability of a data, a test run was administered to fifteen (15) samples, a Chronbach's Alpha score of .904 was yielded. The descriptive method derived from quantitative and qualitative treatments were applied to the data collected to come up with the needed assessments.

In the need assessments it sought to determine the profile of the respondents in terms of degrees, preferences on what course to apply the software and the attitude towards face to face and an online application in consulting their teachers in their academic, curricular and extra-curricular. Descriptive statistics were used to analyze quantitative data gathered during the needs assessment.

The data gathered were used as a basis in the development of online teachers-student application using the v-model as a framework in the software development.

4 Software Development Model

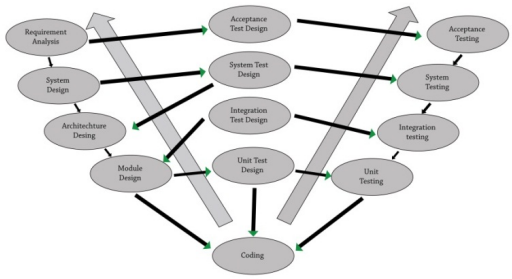


Fig. 1. V-Shaped Model

Online teacher-students consultation application backbone is a product of software development life cycle using V-Shaped model (see Figure 1). This model fits the requirement because at each stage, there is a directly associated testing before proceeding to the next phase [4]. Every stage, a thorough review of the codes and verification from the client on its output is performed before proceeding to the next until system implementation is reached.

Moreover, in this model, the flow of control is iterative. This allows the developer to return to the previous stage if necessary. Since this model provides an earlier feed-

back, review as well as evaluation of the requirements from the users is the upfront monitoring of quality. This ensures that quality software product is produced.

5 Technology Used

The online teacher-student consultation application is a combination of various software and hardware technologies. During the development of the system, JAVA was used as a programming language while J2EE and J2SE in Eclipse IDE were employed as back end programs. For the design of the front end, web technologies such as JAVA SERVLET, JSP, HTML, CSS, JAVASCRIPT, AJAX, JQUERY, DATATABLES AND BOOTSTRAP were utilized. In addition, MYSQL for the database and JBOSS served as the application server for running the web service. Lastly, PUTTY was used to access the Cloud technology for the deployment and storage of the system. As for hardware needs, the developer employed a computer unit equipped with Windows 8 Operating System, i3 processor, 4GB DDR III RAM with 500GB hard drive correspondingly.

Determining user requirements and the technology available to support the development of the application are important factor for the success of this study as confirmed by the recent findings that combining user profile and personalization of design methods are two important elements in the development of an activity to be embedded as a design solution [5].

6 Results and Discussion

6.1 Profile of the respondents according to degrees

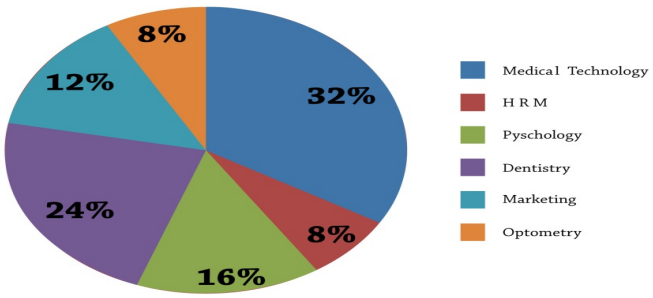


Fig. 2. Profile of the Respondents According to Degrees

A total of fifty (50) respondents were interviewed and surveyed to come up with the needed data for this study. Majority of the respondents are female and in the 3rd year tertiary level. Thirty-two (32%) are taking up Medical Technology followed by

Dentistry (24%). The least in number is enrolled in Optometry and Hotel and Restaurant Management which yielded the same results (8%). Identifying the course of the respondents is important to determine the need for process automation on various degree programs.

6.2 Students Preference on where to apply consultation application

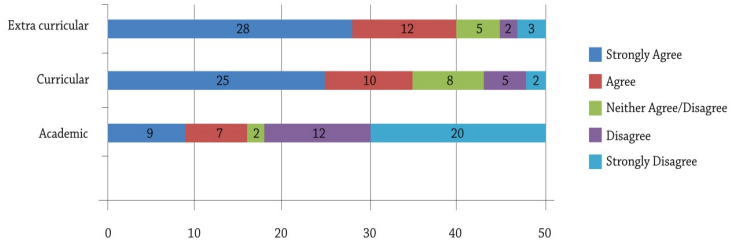


Fig. 3. Students Preference on Where to Apply Consultation Application

The data in Figure 3 suggest that the students preferred online consultation app in their extra-curricular and curricular needs with a majority of the respondents replies that fell on *agree* to *strongly agree*. Queries on extra-curricular consisted of events and activities of student council or organization where the students are affiliated in while curricular needs covered questions with regard to school policies process and deadlines. On the other hand, a bigger portion of the respondents' answers belonged to disagree to strongly disagree to address their academic difficulties. Academic concerns dealt with the help needed for specific subjects enrolled. The data imply that for extra-curricular and curricular matters, respondents believed that an application could be used to help them. It is important to identify students' preference because digital transformation can be a negative factor if not address carefully. [6]

6.3 Consultation method preference per subject

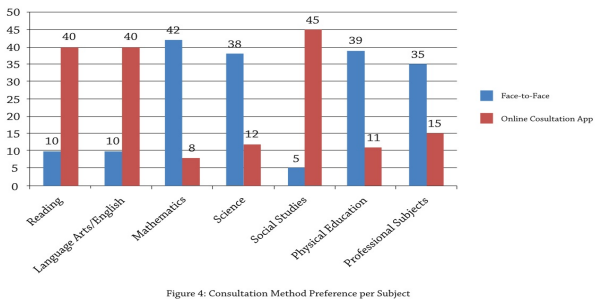


Fig. 4. Consultation Method Preference per Subject

To determine the extent on where online consultation application could be applied, the lists of subjects were included in the questionnaire. As seen in Figure 4, the students still preferred face-to-face in conducting consultations in their Professional, Mathematics, Science and Physical Education subjects. Subjects such as Reading, Language and Social Studies are were the students prefer online consultation application. This supports that an application like teleconsultation has a positive impact as an educational influence to the user [7] as well as using collaborative tool can help improve their academic performance [8]. This data also reflect that teachers handling these subjects may use online consultation application as an alternative to address the needs of their students and schedule appointment to those that still need physical meet up to maximize time and productivity.

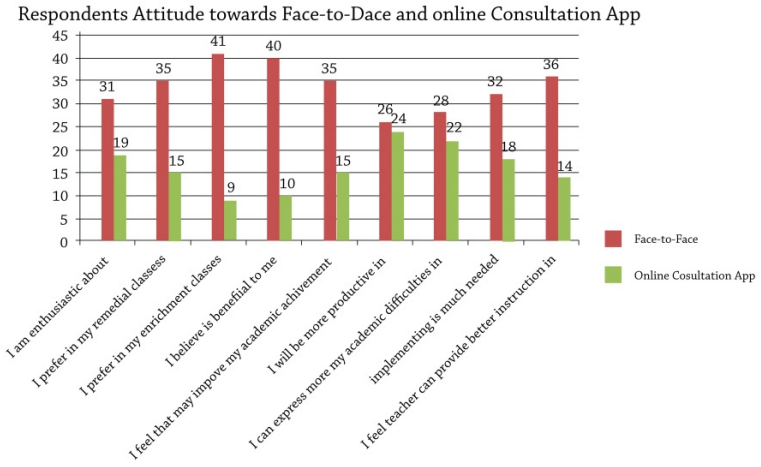


Fig. 5. Respondents Attitude towards Face-to-Face and Online Consultation App

The results of the respondents' attitude towards face-to-face and online consultation application were also examined. As shown in Figure 5, majority of the respondents still preferred face-to-face consultation. A slight difference between the two methods was associated with in terms of productivity and expressing their difficulties. Though the number suggests in favor with physical meet ups, there are still students who would like to try online consultation application. In medical field the teleconsultation application is accepted by fifty (50%) of patient without any requirements for further specialist [9]. Undoubtedly, teachers could provide schedule for the two modalities and students get to choose the one appropriate for them to address their specific concerns. This validates that the use of mobile learning has provided a new learning experience for teachers and parents to teach children [10].

7 How Does It Work?

The following use cases describe what tasks could be performed by the user on the application. The illustration shows the presence of module to do task to perform consultation. This confirms that procedures are more automatable when the processes are well defined [11].

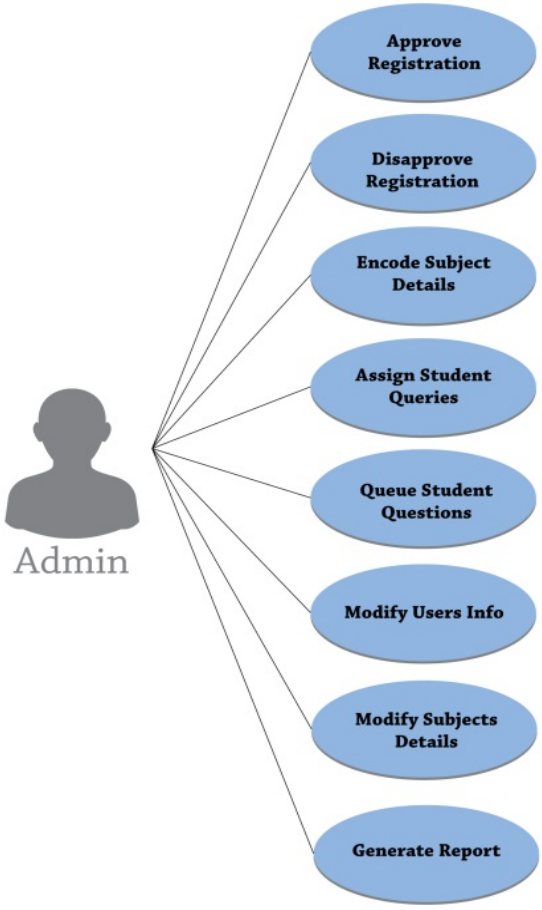


Fig. 6. Use Case Diagram – Administrator Role

This use case (see Figure 6) describes the functions of an administrator. Upon receiving the registration requests of both faculty and students, the administrator will approve or disapprove such requests. All information received during registration can be modified as well as the encoded subject details. This information will be viewed by students and teachers for their perusal. After the students send a message (academic, curricular and or extra-curricular), to their teachers, the administrator queues the que-

ry to the assigned teachers. A report may then be generated containing teachers' ratings for documentation purposes. Automating process like this will free people from doing repetitive tasks, increasing their productivity and there is 24X7 availability of service [12].

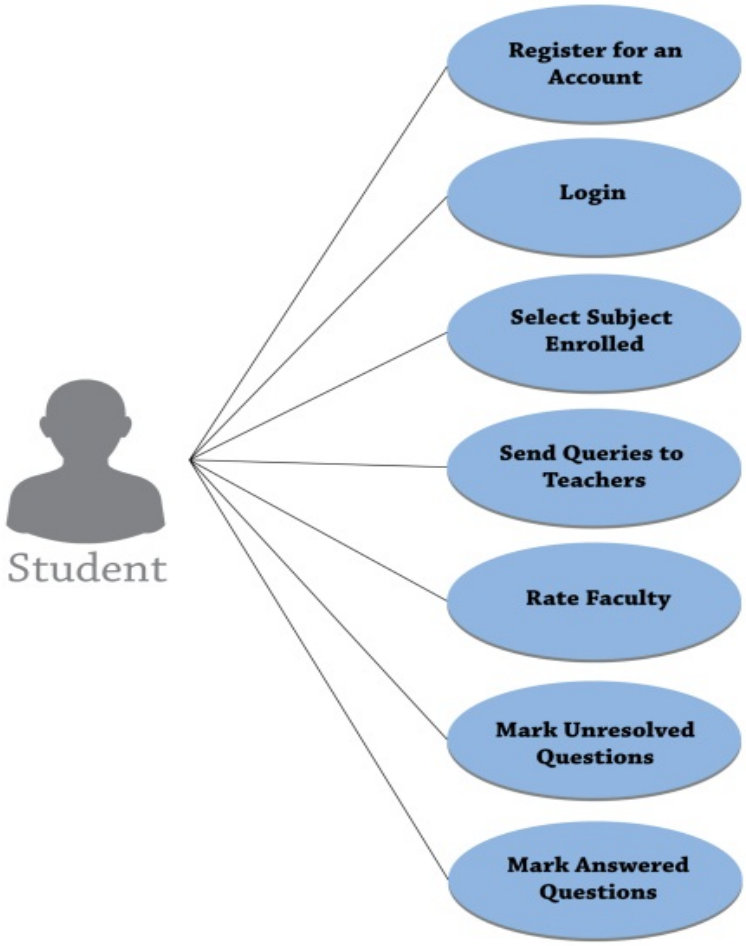


Fig. 7. Use Case Diagram – Student Role

Meanwhile, to initiate the access of the students to the application, an approved registration is needed as seen in this use case (see Figure 7). Username and password serve as the key to log-in to the system which is part of the requirements during registration. Once the students gain access to the system, they select the subject and send queries to the assigned teacher on either academic, curricular and extra-curricular concerns. The students can mark questions whether they were answered or still unre-

solved and then rate the faculty as regards his or her ability to deal with their issues. For those questions that were marked unresolved, this will be lined up again by the administrator accordingly and may be assigned to a different teacher until students become satisfied with the responses.

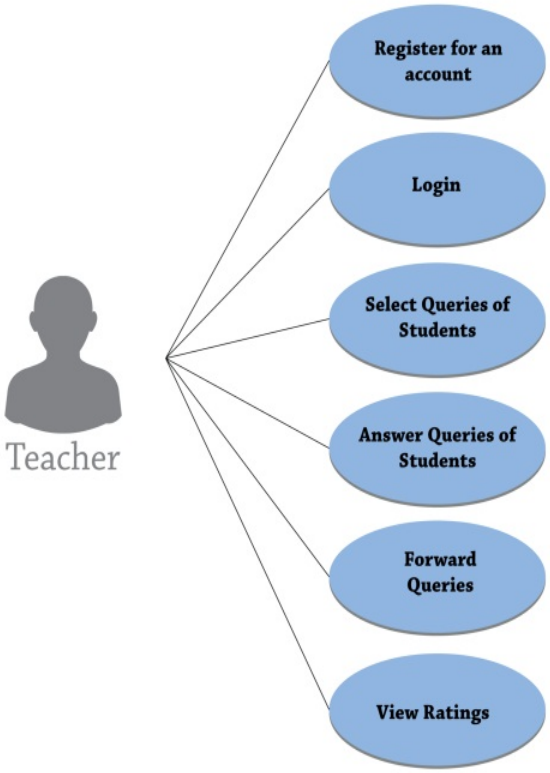


Fig. 8. Use Case Diagram – Teacher Role

Similarly, teachers need to register to get access to the application as seen in this use case (see Figure 4). A valid username and password is needed to use the system. The teacher will then select their subjects, answer queries of the students and forward queries to another teacher if his or her knowledge is inadequate on the topic at hand. The teacher can likewise view the ratings given by the students.

8 Contribution to Scholarship

Currently, there is no existing online consultation application dedicated for teachers and students. Most consultation application was for clinical use to solve geograph-

ical distance between patient and health care providers [13]. In education sector, some schools used teleconsultation to support children with disabilities [14] but not as a way to assist students in their academic difficulties as a common tool for all. This interactive and innovative software application truly encourages collaboration of the faculty to another faculty to help students with their needs varying from academic, curricular and extracurricular. Additionally, the software provides data that when mining techniques were applied; it could present information for faculty efficiency based on the ratings provided. This can serve as a substantial basis for curriculum evaluation as well in accordance with the queries that commonly appear among students. More importantly, an intervention program for those identified students who need habitual assistance may be developed to help them cope with their various needs.

On the administrative side, the user has full control of the system including those functions that the programmer does during maintenance like archiving of records. Since all the softwares that will be used to come up with the application from the design as well as the data base and backend tools were open source, the application will work in any operating system and browsers.

In the implementation stage, a cloud computing solution provider that can offer at least 4 core processor, 16 GB of memory, 320 GB of SSD and 6TB of data transfers is the best hardware requirements to consider. An adequate technical support, the rightful owner of the application and the data have to be clearly stipulated in the contract before, during and after new version is uploaded or another cloud provider is employed. Moreover, the current app is well supported should its integration for mobile app and other platforms in the future may be required.

9 Conclusion

Using the results of the needs assessment, the features of the developed application respond to different types of queries which were categorized into extra-curricular, curricular and academic. The students have expressed their willingness to use the app to inquire on school policies, processes, activities and events. While the results of the survey reveal that this application will not replace the traditional physical meet ups for their academic needs, subjects like Reading, Language and Social Science were identified on where it could be beneficial. This online teacher-student consultation application promises a new alternative in addressing the concerns of students. For future studies, the output generated by this app when data mining technique is applied could provide information on faculty efficiency, curriculum evaluation and intervention program.

To Access the procedures on how to use the application the following videos are posted via You tube:

Online Consultation App -- Account Registration
https://youtu.be/VUC5dAOnFIU
Online Consultation App -- Admin Process Video
https://youtu.be/BMqBRHf3EVY
Online Consultation App -- Process Flow Video

https://youtu.be/yV5s2fXfdtg
Online Consultation App --Student Process Video
https://youtu.be/M_2bJqfkfho
Online Consultation App --Teacher Process Video
https://youtu.be/roEM_NUMG0c

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Quality of Experience in Mobile Applications: A Systematic Mapping of Metrics and Tools

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Abstract—Context: Quality of Experience (QoE) enables the description of user perceptions about the performance of a particular application or service. In the mobile computing context, it is an important measure for service providers and users, since QoE makes it possible to improve it and make it more competitive to achieve user fidelity. In turn, the importance of QoE in mobile technologies increases due to the various factors that affect the applications that run on mobile devices.

Objective: The purpose of this study is to identify the metrics and tools relevant to the scientific community for the QoE analysis of mobile applications.

Method: A systematic mapping study was conducted.

Results: From a total of 751 studies, 33 were selected, and 13 metrics and 15 mobile QoE analysis tools were identified.

Conclusions: The existing mobile QoE analysis tools collect and calculate metrics automatically, combining objective and subjective metrics. However, they present limited approaches, making it difficult to carry out an integral analysis of the applications.

Keywords—Quality of experience, mobile applications, systematic mapping, metrics, tools.

1 Introduction

Mobile applications and services are increasingly present in most aspects of daily life, satisfying information, communication and entertainment needs. To achieve the acceptance of users in the use of mobile applications, it is necessary to consider the Quality of Experience (QoE), which allows to measure the quality of an application based on the user perception [1], as well as different factors that affect such quality.

Different concepts about QoE can be found in the bibliography, in [2] QoE is defined as the general acceptance of an application or service according to the subjective perception of the end user, being influenced by the context and user expectations. According to [3] QoE is the measure of the user performance based on objective and

subjective psychological measures about the use of an application or service. QoE represents the level of acceptance that users perceive when making use of an application or service, presenting as main characteristics subjectivity, user centeredness, integrality and multidimensionality [4].

QoE is an important measure in the context of mobile computing due to the characteristics of mobile devices: heterogeneity of devices and operating systems, types and functionality of applications, user profile, mobility, context, network connectivity and infrastructure. This leads to the appearance of multiple factors that directly intervene in the quality of mobile applications, making it necessary to take into account these factors for the analysis of the QoE in this type of devices.

Therefore, QoE in mobile applications constitutes a relevant issue for the scientific community, mobile application development communities, service providers and users, evidencing a growth in research related to this topic. This study focuses mainly on two aspects of QoE, the first is the theory to analyze it (QoE metrics) and the second is the software used to perform its analysis (evaluation, calculation, estimation, measurement, etc.) [1].

QoE metrics are classified as objective and subjective. Subjective metrics are related to the users opinion, evaluating the quality of the application or service based on their experience with the application [4]. This depends on subjective factors such as context and user expectations about the application. In general, subjective metrics are based on conducting surveys and questionnaires to the users. This processes presents the difficulty of being costly in terms of time and money [5], [6].

Regarding objective metrics, its systematic nature stands out, they are exact and repeatable, and refer to different properties such as data presentation time, consumption of mobile data, energy consumption, user interface and content presentation [4].

Several investigations analyze the QoE in close relation with the Quality of Service (QoS), while QoS degradation causes an unacceptable QoE. The QoS parameters related to network performance such as delay, instability, loss rate, error rate, bandwidth and signal success rate are used to determine the QoE value, depending only on the calculation of the QoS [1].

The objective of this study is to carry out a systematic mapping study on QoE metrics and tools for mobile applications, identifying the most researched metrics and their application in the use of tools for QoE analysis. The paper is organized as follows: Section 2 describes the methodology used; Section 3 presents the results obtained; Section 4 analyzes and discusses the results of systematic mapping; and finally, in Section 5 the conclusions of the study are presented.

2 Methodology: Systematic Mapping Study

The systematic mapping technique allows us to review and categorize information related to a specific topic or area of interest. The objective of a systematic mapping is to determine the scope of the research conducted on a specific research topic and to classify knowledge [7]. Figure 1 presents the process that has been followed for the systematic mapping.

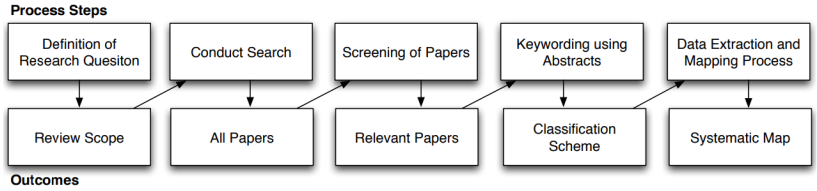

Fig. 1. The systematic mapping process [7]

2.1 Definition of research questions

The research questions focused on identifying the most commonly used metrics and existing tools to analyze the quality of experience of mobile applications. Thus, the following questions for systematic mapping were raised:

1. What metrics have been proposed in the literature for the analysis of QoE in mobile applications?
2. How have these QoE metrics been applied?
3. What tools (framework, systems, algorithms, applications, etc.) have been proposed for the QoE analysis of mobile applications and what are their characteristics?

2.2 Conduct search

One search was conducted using ACM, IEEE, Springer and ScienceDirect as main data sources, and another search was made following the references in the found articles. The following keywords were used to perform the search: quality of experience, metrics and mobile applications. A small set of documents was obtained by forming a search string with these keywords. It was necessary to adjust the final search string to obtain more comprehensive results. Finally, the following search string was formed: "(QoE OR quality of experience) AND (metrics) AND (mobile)". After executing the search on data sources and the reference review, a total of 751 articles were obtained.

2.3 Screening of papers

The selection process was done by analyzing the title, summary and keywords of the articles. The following inclusion criteria were considered:

- Studies carried out since 2008.
- Studies published in English.
- Studies on QoE in mobile applications.
- Studies on tools for the analysis of mobile QoE.

And the following exclusion criteria:

- Studies in the form of summaries or presentations.
- Studies whose main focus was not related to the mobile computing area.

2.4 Keywording of abstracts

The relevant information regarding the systematic mapping process was oriented mainly towards determining the elements related to the quality of experience in mobile applications:

- Quality of experience (QoE).
- Quality of service (QoS).
- Mobile application.
- Metrics.
- Tools.

These elements and the related aspects were considered for the grouping and classification of the studies using the classification scheme described below.

2.5 Classification scheme

Once the relevant articles were selected, a first classification was defined based on the contents of the study (Fig. 2):

- Dimension of Metric: empirical studies in which a set of metrics for the analysis of QoE in mobile applications are analyzed.
- Dimension of software: studies in which tools, frameworks, systems and/or applications are developed and/or applied to analyze QoE in mobile applications.

A second classification considered the types of metrics analyzed (Fig.2):

- Dimension of objective metrics: studies focusing on objective metrics.
- Dimension of subjective metrics: studies focusing on subjective metrics.

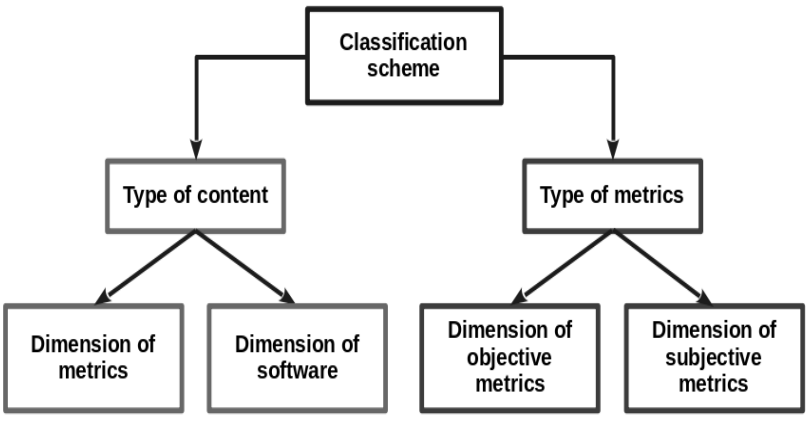

Fig. 2. Classification scheme

2.6 Data extraction and mapping process

After defining the classification scheme, the last step of the systematic mapping consists in the extraction of data and the process of mapping the different dimensions. To carry out this process, it was necessary to review the content of the selected articles. The results of this last stage are shown in the next section.

3 Results

This section shows the results of the mapping process and the data extraction from the selected studies in order to answer the research questions. Table 1 and Table 2 show the number of studies associated with the dimensions of the classification scheme, grouping the studies by the type of content and the type of metrics analyzed.

In the dimensions of the second classification an overlap of the studies in both dimensions can be observed. This is due to the fact that several articles address both the analysis of objective and subjective metrics.

Figure 3 illustrates a bubble chart with the dispersion per year of the studies selected according to the classification scheme. The size of the bubble is proportional to the number of items that are located in the intersection of each dimension with the corresponding year.

Table 1. Number of articles by type of content

Dimension	Quantity
Dimension of metrics	17
Dimension of software	16

Table 2. Number of articles by type of metrics

Dimension	Quantity
Dimension of objective metrics	17
Dimension of subjective metrics	16

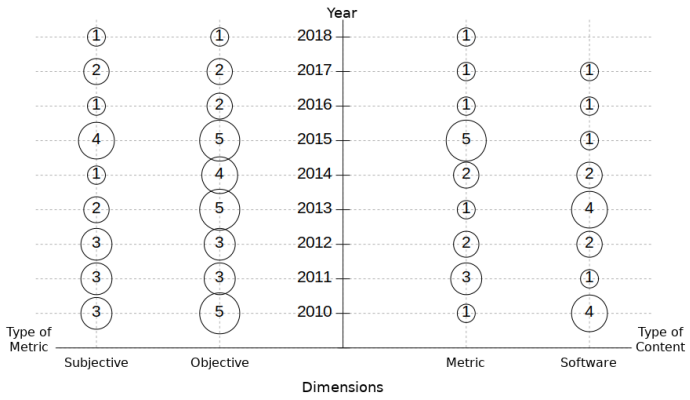

Fig. 3. Distribution of studies per year in each dimension

3.1 Data extraction and mapping process

In order to answer the first and second research question, the quality of experience metrics analyzed in the selected articles were identified, yielding a total of 13 metrics of QoE. Each of the identified metrics is presented below.

Latency [1], [4], [8]–[17]: It measures the length of time it takes for a packet to travel from the origin to the destination. It is measured by sending a packet that has a response. The latency is measured by the time it takes from the moment the packet is sent until the response is obtained.

Signal instability [4], [10], [13], [18], [19]: It defines the variation in the arrival time of the packets, caused by network congestion, loss of synchronization or by the different routes followed by the packets to reach the destination. One of the best-known ways to determine the instability of the signal consists of the average of the delay variation between the received packets.

Signal strength [12], [13], [15], [16], [20]–[22]: It is a reference scale for measuring the power level of the signals received by a device in wireless networks. The signal strength refers to the received intensity and not to the signal quality.

Bandwidth-Throughput [4], [8] [13], [17], [20]–[25]: Technically, throughput is the information capacity that a network element can transmit in a certain period of time. The bandwidth is the available theoretical capacity of a link and the throughput is the actual usage level of the link. To measure it, the Iperf tool can be used by sending data streams, indicating the amount of data transferred and the throughput measured.

Mobile data consumption [5]: It corresponds to the volume of data used by an application using mobile data, which can mean a cost to the user. One way to measure data consumption is by determining the volume of data used over a period of time by a particular application or service.

Energy consumption [4], [5], [12], [13], [22], [24], [26]–[29]: It is a factor that constantly influences the user experience on mobile devices, since it limits the use of the device, especially when the battery is completely discharged. In mobile devices it can be measured in percentage or in milliamperes-hour (mAh).

CPU consumption [12], [13], [22]: It describes the capacity of the processor used by an application. The CPU consumption of a mobile device may vary depending on the types of tasks that an application performs. This value is measured in percentage.

Memory consumption [12], [13]: It is the amount of memory (RAM) used by an application when it is running. It is used to store the internal data and instructions of the application. The memory limits the number of applications that the users can execute and the amount of data with which they can work.

Packet loss [4], [8] [10], [12], [13], [15], [17], [18], [20], [22]: It occurs when one or more data packets traveling through a computer network do not reach their destination. It is usually caused by network congestion and it is measured as a percentage of lost packets with respect to the total number of packets transmitted.

User perceived latency [5], [26], [30] [32]: It is a metric of the application level. It is defined as the time it takes the application from the moment that the user starts an action until the data is displayed in the interface.

Audio quality [8], [15], [18], [20]: It is the sound quality perceived by the user. This parameter can be analyzed subjectively. However, it can be determined by some properties of the audio file (Kb/s, signal/noise, frequency (Khz), etc.).

Video quality [4], [10], [14], [15], [18], [20], [24], [25], [33] [35]: Just like the audio quality, it is a subjective parameter that may depend on the user. However, there are several properties of a video file that allow for the automatic determination of the quality of the video (complexity of the scene, movement level, image quality, corrupted or missing data, etc.).

User opinion [1], [4], [8], [10], [12] [15], [18], [19], [21], [23], [33], [34], [36]: It is a subjective parameter for the analysis of the quality of experience. It indicates the level of general satisfaction of users regarding an application. The most common method is through the mean opinion score (MOS) representing the quality perceived by the user translated into values from 1 to 5 (a higher value means higher QoE).

3.2 QoE tools

Below is the list of QoE tools identified in the selected articles. The type of software, its objective (analysis, monitoring and prediction) and its description are defined. A total of 15 tools were identified, responding to the third research question.

QoE Doctor [5]: It is a software tool for the analysis and monitoring of QoE in mobile applications without the need to access the source code of applications. It consists of the implementation of a mobile application for the analysis of the main causes of QoE problems across the application, transport, network, and cellular radio link layers. It makes use of user interface automation techniques to reproduce user behavior related to QoE, and measures the latency perceived by the user directly from changes in the user interface.

Prometheus [20]: It is a monitoring and prediction system of QoE in real applications of video on demand and VoIP. It consists of implementations in both the mobile device and the service operator. It estimates QoE metrics that address the specific challenges of cellular operators of lack of control, limited points of view and complexity of the protocol. It does not require control over the services of the target application and makes QoE predictions using only passive network measures.

AppInsight [30]: It is an analysis and monitoring system that helps mobile application developers to diagnose the performance of their applications. It consists of the communication between an implementation on the mobile device and a web server. It collects tracking data to discover critical routes and exception routes in user transactions, indicating the optimizations needed to improve the user experience to developers. It is light and does not require any modification of the operating system, or any contribution from the developer.

Proteus [17]: It is a QoE monitoring and prediction framework that passively collects information about network performance observed by applications. It uses regression trees to decipher network performance patterns, and forecasts future network performance to benefit the application's performance. Proteus can predict the occurrence of packet loss, the occurrence of a long delay and the performance of the network with an error of 10kbps with an average performance range of 100 to 800 kbps.

Timecard [31]: It is a system of analysis, monitoring and prediction that helps manage end-to-end delays for interactive mobile server-based applications. It consists of the communication between an implementation on the mobile device and an API on a web server. It provides two abstractions: the first returns the time elapsed since the user started the request, while the second returns an estimate of the time it would take to transmit the response from the server to the client and process the response at the client. For any user transaction, Timecard tracks the elapsed time and predicts the remaining time, allowing the server to adjust its working time to control the end-to-end delay of the transaction. Timecard incorporates techniques for tracking delays in multiple asynchronous activities, managing the time bias between the client and the server, and estimating network transfer times.

Panappticon [32]: It is a system of services and applications for the analysis and monitoring of QoE through event tracking related to the application in the operating system and framework libraries. It correlates the related events and identifies the individual transactions perceived by the user. Panappticon determines the duration and critical path of each transaction, which helps to clarify the root causes of performance bottlenecks. It monitors application software, system and kernel layers. It can identify performance issues resulting from application design flaws, low power hardware and harmful interactions between seemingly unrelated applications.

PowerTutor [28]: It is a mobile monitoring application to show the power consumed by a set of system components such as CPU, network interface, screen, GPS and other applications. It receives the current values in mA from the controller and then multiplies the value by the voltage that is basically the battery of the smartphone. PowerTutor calculates the energy consumption of applications and services based on processing times and it is only available for specific types of phones.

YoMoApp [25]: It is a mobile analysis and monitoring application for the Android platform that accurately reproduces the behavior of YouTube service in order to monitor and store passively the key performance indicators of YouTube's adaptive video streaming on smartphones. It monitors user events, buffer level and video quality. The monitored data is used to analyze YouTube's mobile QoE.

IVQA [35]: It is an algorithm for the monitoring and prediction of instantaneous video quality. It presents a constant execution time appropriate for its implementation in real time applications on light devices. It is based only on the parameters that are calculated during the video encoding process.

ARO [22]: It is an analysis and monitoring tool that works through a mobile application and a desktop application. It exposes the interaction between the state of the radio resource channel and the transport, application and user interaction layers in order to reveal the inefficient use of resources by mobile applications. ARO helps developers identify resource usage inefficiencies and improve their applications.

Mobile Agent [12], [13]: It is a mobile application with three monitoring entities that check different aspects of a mobile application: quality of service, contextual and experience monitoring. This tool is the fundamental component of an architecture that runs in laboratories with controlled environments.

QX-probe [26]: It is a comparative and quantitative QoE analysis and monitoring tool to identify application adjustment points. It is based on the execution of a service

on the mobile device that communicates with a web server. QX-probe defines the latency perceived by the user and the energy consumption as critical factors for the analysis of QoE at user interface level. It provides a web tool for the analysis of QoE and the detection of adjustment points.

Agboma & Liotta [10]: It is a management framework for the analysis and prediction of QoE for different types of multimedia content on three types of mobile devices: mobile phones, personal digital assistants and laptops. It uses a statistical modeling technique that correlates the QoS parameters with the estimates of users' QoE perceptions.

ExBox [9]: It is a middlebox based on a hardware device and a software. It can learn the experiential capacity of a network through the estimation of QoE and machine learning. ExBox performs the analysis and monitoring of QoE metrics in the application and uses light machine learning techniques that are designed for dynamic wireless environments.

Keytko et al [18]: It is a framework for the analysis and monitoring of mobile QoE in video transmission. It combines objective and subjective parameters to evaluate user experiences. It performs the measurements of network parameters on the server and user feedback on the device through a mobile application.

After having the list of metrics and software tools for the analysis of mobile QoE, Table 3 was designed, showing the identified tools in relation to the metrics considered for the analysis of the quality of experience.

Table 3. Relationship between tools and metrics of mobile QoE

Tools / Metrics	Latency	Signal instability	Signal strength	Bandwidth	Mobile data consumption	Energy consumption	CPU consumption	Memory consumption	Packet loss	User perceived latency	Audio quality	Video quality	User opinion	Total
QoE Doctor					x	x				x				**3**
Prometheus			x	x					x		x	x		**5**
AppInsight										x				**1**
Proteus	x			x					x					**3**
Timecard										x				**1**
Panappticon										x				**1**
PowerTutor	es					x								**1**
YoMoApp				x								x		**2**
IVQA												x		**1**
ARO			x	x		x	x		x					**5**
Mobile Agent	x	x	x	x		x	x	x	x				x	**9**
QX-probe						x				x				**2**
Agboma & Liotta	x	x		x					x			x	x	**6**
ExBox	x			x					x					**3**
Keytko et al		x							x		x	x	x	**5**
Total	**4**	**3**	**3**	**7**	**1**	**5**	**2**	**1**	**7**	**5**	**2**	**5**	**3**	

4 Discussion

According to the classification scheme defined in the methodology, the articles belonging to the dimensions of the first classification (Table 1) present a balanced distribution. Therefore, those dedicated to QoE metrics (17 articles) and those focusing on the development and/or application of tools, frameworks, systems and applications for QoE analysis (16 articles) have been addressed similarly by the scientific community. However, in the second classification (Table 2), it is observed that the objective metrics (30 articles) present greater interest of study and application by the scientific

community with respect to the subjective metrics (20 articles). Furthermore, it is clear that several of the studies address subjective metrics such as the opinion of users to analyze QoE, in order to make comparisons and validations of QoE analysis methods based on objective metrics.

The monitoring of values obtained from QoE metrics is a common feature in the tools identified. Another characteristic present in most of the tools was the subsequent analysis of the collected data associated with the calculation of the metrics. However, the prediction of future QoE values is only present in a minority of tools, which are mainly oriented to the video quality analysis of applications and multimedia services.

As seen in Table 3, the metrics most commonly used by QoE tools include: bandwidth, power consumption, packet loss and latency perceived by the user. On the other hand, the least frequently used metrics correspond to mobile data and memory consumption, and audio quality.

The identified software tools present a wide dispersion of the metrics used to analyze QoE in mobile applications. On average, each of the metrics is analyzed in only three tools and at the same time each tool covers only three or four metrics of QoE. Therefore, if a user, developer or network operator needs to analyze the QoE of an application or mobile service in order to identify failures and improve them, s/he cannot do it with a single tool. On the other hand, they offer little support when analyzing only certain quality attributes. Thus, multiple factors that affect the QoE related to the characteristics of the devices and the context are not taken into account. These tools present limited approaches, making it difficult to perform an integral QoE analysis in mobile applications.

5 Threats to Validity

A threat to validity of this study is whether a correct selection process was conducted. The research questions, inclusion and exclusion criteria were defined before the execution of systematic mapping in order to ensure an unbiased selection process. To improve validity and mitigate any partiality, the inclusion and exclusion of articles was decided jointly by the authors. However, the threats from a quality assessment perspective cannot be ruled out, since no scoring system was used for each article in the selection process.

Another threat to validity is the inclusion of all relevant articles in the area. Therefore, several main sources of data related to the area and the references of the studies found were taken into account. In addition, each of the studies returned by the data sources were analyzed, and it was necessary to adjust the first search string in order to obtain more comprehensive results. The classification scheme may also represent a threat to the validity of this mapping study. One of the problems with mapping studies is how to determine the correct way to categorize the resulting articles.

6 Conclusion

In the present research, a systematic mapping study was conducted on metrics and tools of mobile quality of experience, in which 33 articles relevant to the topic were selected from a total of 751 articles from different sources and references.

The preliminary results of the study allowed us to identify the main interests of researchers in the area of metrics and tools for QoE analysis in mobile applications. The principal proposed metrics in the selected relevant articles and their use in the context of mobile applications were identified. On the same lines, the tools proposed by the researchers for QoE analysis and their characteristics were identified. Differences and similarities among tools and their relationship with the metrics identified were determined.

Several tools were identified for the mobile QoE analysis that collect and calculate metrics automatically, combining both objective and subjective metrics. However, they present limited approaches which make it difficult to perform an integral analysis of the applications. This leads to the existence of a gap in the development of tools that integrate and combine mobile QoE metrics.

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Experimental Verification of two Theoretical Solutions of the Pendulum for Large Angles in Frequency Domain for Teaching Support

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Abstract—During pendulum analysis, the approximation for small angles is usually performed as a simple harmonic motion. However, for large angles this approximation is not convenient so exact solutions are proposed by different methods. This paper presents the comparison of two solutions for the displacement of the pendulum in the domain of time and frequency, the solution by Jacobi elliptic function and the solution by the numerical method Dormand-Prince with the results of measurements obtained by means of a physical prototype designed for the teaching of physics. We consider that this comparative study allows a better understanding of the phenomenon of the non-linear pendulum in the students of undergraduate careers in the physics of waves as well as a previous training for the course of analysis of signals being in good exercise of teaching.

Keywords—Technology-enhanced learning, Pendulum, frequency domain, exact solution, Fourier analysis, numerical methods

1 Introduction

Technology-enhanced Learning (TEL), which is based on the advance of information and communication technologies, allows students to acquire a deeper knowledge of the phenomena and concepts studied. On the other hand, it is also clear that new generations feel very comfortable with intelligent mobile devices and it is undeniable that these technologies have permeated the classroom because a technology-enhanced environment offers students the opportunity to design and implement experiments, explore the relationships between variables and thus learn scientific concepts [1,2].

The teaching of physical phenomena has been strongly permeated by technologies, from laboratory instrumentation systems, remote access to physical laboratories, virtual environments for experimentation and intelligent mobile devices [3–6] which has allowed an important advance in the didactics of learning [7].

One of the non-linear systems widely studied in both introductory and advanced mechanical physics courses is the simple pendulum [8–15]. The differential equation that models the simple undamped pendulum is given by (1):

$$\frac{d^2\theta}{dt^2} + \omega_0^2 sin\theta = 0 \tag{1}$$

with $\omega_0 = \sqrt{\frac{g}{l}}$.

Different types of solutions to the equation (1) have been defined. In [16] it is proposed that the angular displacement θ of a mass μ oscillating in a vertical plane supported by a massless string of length l described by the non-linear differential equation (1), has a solution through Jacobian Amplitude Function $am(x, m)$ as (2):

$$\theta(t) = 2am\left[\left(\frac{g}{ml}\right)^{\frac{1}{2}}; m\right] \tag{2}$$

where $m = \frac{2\mu gl}{E_0}$, and E_0 is the total mechanical energy, which is constant for the system.

In [11,17] it is argued that the solution for (1) is given by (3) in the following way:

$$\theta(t) = 2arcsin\left\{sin\frac{\theta_0}{2} sn\left[K\left(\sin^2\frac{\theta_0}{2}\right) - \omega_0 t; \sin^2\frac{\theta_0}{2}\right]\right\} \tag{3}$$

with θ_0 that is the initial amplitude and K is the complete elliptical integral of the first kind defined as:

$$K(m) = \int_0^1 \frac{dz}{\sqrt{(1-z^2)(1-mz^2)}} \tag{4}$$

In (3) $sn(u; m)$ is the Jacobi elliptic function [18].

On the other hand, solutions to differential equations can be found by numerical methods such as the Dormand–Prince [19,20] that can solve problems of initial value from (5).

$$y_{(n+1)} = y_n + h\sum_{i=1}^{s} b_i k_i \tag{5}$$

1.1 Problem of research

This document discusses the problem of teaching the pendulum movement as a composite harmonic movement for large angles from the frequency frame of reference. Frequency study is proposed because the study of the pendulum for introductory courses is usually done in the time domain where waveforms are studied as simple harmonics given that visually they seem so and that mathematical approximations demonstrate it in the same way.

1.2 Research focus

The research focuses on determining the different forms of solution that exist as reported in a review of the systematic literature, then develops a method of solution by numerical approximations and finally captures data from a physical system. An algorithm is developed that allows to visualize the results in the frequency domain for analysis and comparison finding an important correlation between the results that would not be possible to analyze with the students of the introductory courses with the signals in the time domain.

2 Numerical Solutions

Two theoretical solutions have been implemented for the development of this work. The first is developed by means of the exact solution for the pendulum of the equation (3). In this procedure the Jacobi elliptic function is found from the routine of Matlab® as in Figure 1.

```
% Calculation of the Jacobi elliptic functions
m = (sin(theta_0/2))^2;
K_m = @(x) 1./(sqrt((1-x.^2).*(1 - m * x.^2)));
Km = integral(K_m,0,1);
w_0 = sqrt(g/l);
[SN,CN,DN] = ellipj(Km - w_0 .* t,m);
theta_t = 2*asin(sin(theta_0/2).*SN);
```

Fig. 1. Algorithm to calculate the Jacobi elliptic functions

The second solution has been proposed by numerical methods using the Matlab® ODE45 package with which the second-degree differential equation has been solved and the solution has been obtained in time for the displacement of the pendulum.

The parameters that have been used for the solution are presented in Table 1

Table 1. Parameters used for solution.

Parameter	Value
l	$0{,}8m$
θ_0	$\pi/2\ rad$
t	$9s$
Δt	$0{,}01s$
g	$9{,}8m/s^2$

For the presentation of the results the Fast Fourier Transform is used [21], in this way it is possible to observe the results in the frequency domain since the variations in the time domain are not perceptible in the graphs found. Single-Sided Amplitude Spectrum is presented.

Fuourier's discrete transform is defined by (6):

$$Y(k) = \sum_{j=1}^{n} X(j) W_n^{(j-1)(k-1)} \tag{6}$$

3 Experimental Implementation

For the capture of experimental data, a prototype of a pendulum used as a didactic tool in wave physics laboratories has been implemented [21]. The prototype is presented in the Fig. 2.

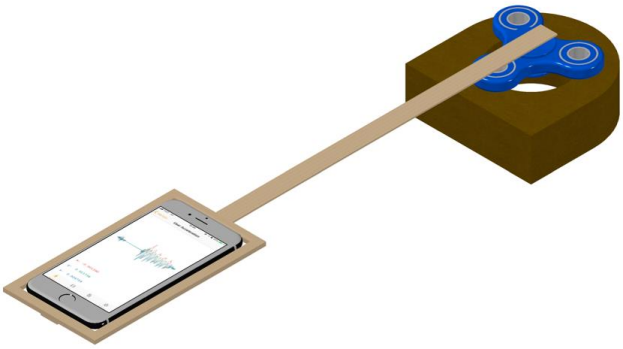

Fig. 2. Experimental prototype developed for physics didactics

The prototype is implemented in a heavy support to fix it in flat surfaces to which a fixed spinner is stuck, from its central axis the bar of despicable mass is fixed and at the end a support for the mobile device own of the student. Data is captured in real time through the application phyphox [22].

4 Results

In Figure 3 the signals obtained as a function of time are displayed. In the signal obtained with the numerical method is observed that there is an increase in the period of the signal, this increase is because the calculation by the method Dormand-Prince generates a delay to take previous steps to generate subsequent steps.

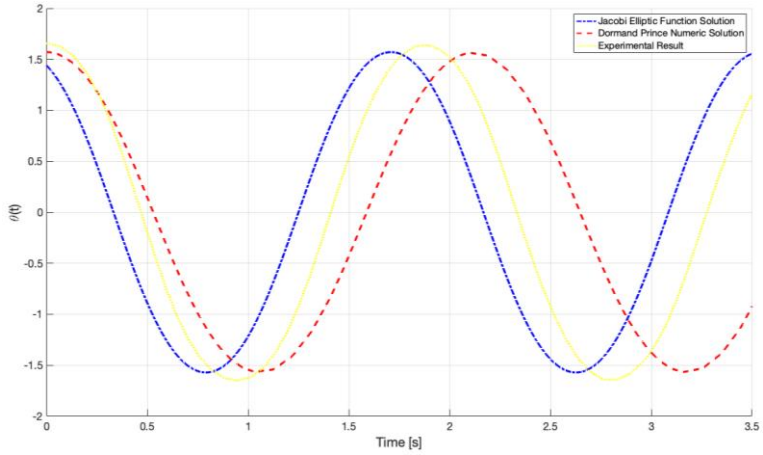

Fig. 3. Experimental prototype developed for physics didactics

Figure 4 shows the frequency analysis of the three signals presented in Figure 3.

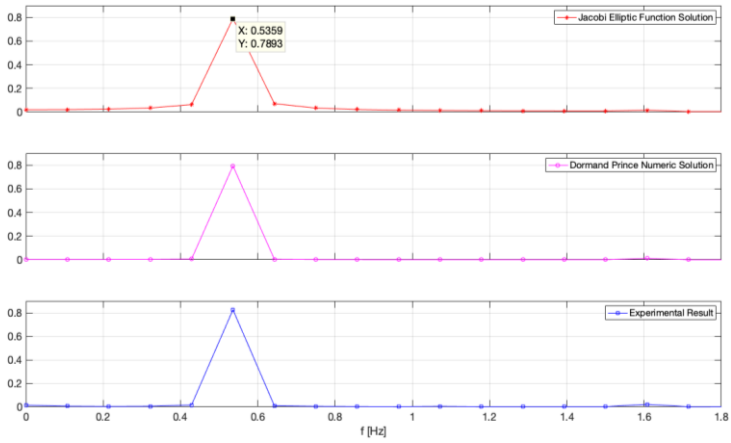

Fig. 4. Time signals

The theoretical period of the system is given by (7) [23].

$$P = \frac{2P_0}{2}\int_0^{\pi/2} \frac{d\theta}{\sqrt{1-k^2\sin^2\theta}} = 1{,}8351 \tag{7}$$

where $P_0 = 2\pi\sqrt{\frac{l}{g}}$ is the period with small angles. With the above result the fundamental frequency is $f = 0{,}5449Hz$.

In Figure 5 zoom in amplitude to the signals in the frequency to see the 3th harmonic for the three solution cases.

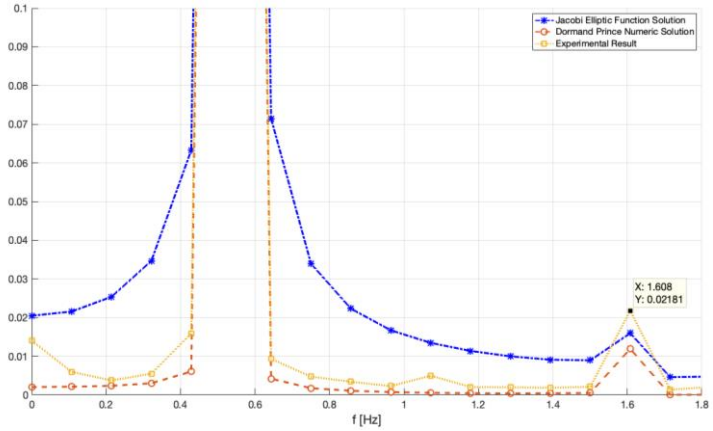

Fig. 5. Comparison of the 3rd harmonic

Figure 6 shows the zoom for the 5th harmonic, the exact solution by the Jacobi Elliptic Function due to the continuous amplitude shows the harmonic in a very reduced form. The experimental measurement shows the highest relative amplitude of the 5th harmonic. Also observed in the numerical solution are the 7th, 9th, and other odd harmonics that are also in the experimental result that are masked by the noise in the signal.

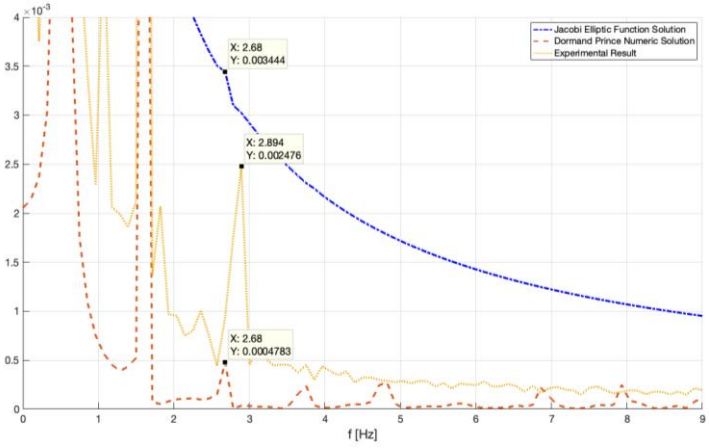

Fig. 6. Comparison of the 5rd harmonic

Frequency components can be shown in the signal by means of the expansion in Taylor series of the function $\sin\frac{\theta_0}{2}$ as (8) [13].

$$\sin\frac{\theta_0}{2} = \sum_{n=1}^{\infty} \frac{(-1)^{n+1}\theta_0^{2n-1}}{2^{2n-1}(2n-1)!} \tag{8}$$

In Figure 7 Frequency components are shown in bar format for better comparison.

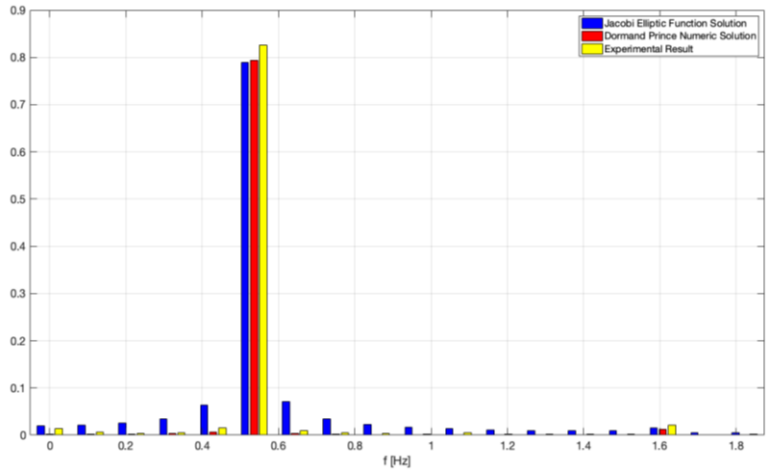

Fig. 7. Bar graph of the first harmonics in three signals

5 Discussion

From the results it can be found that for larger angles the analysis of the signal as a pure periodic signal is not intuitive, this is because other components of low amplitude appear that are not perceptible in the periodic wave. From the frequency analysis it was possible to verify that there are harmonics, which for the analyzed case, corresponds to the 3th that appears both in the two mathematical solutions and in the experimental data that can be observed in detail in Fig. 5. There are also odd harmonics of higher frequency that can be demonstrated with the solution of the equation in Taylor series [24]. Analysis in the frequency domain allows a deeper understanding of the phenomenon of pendulum displacement as a harmonic system composed of different odd frequencies. The results show that the graphic analysis in time domain is not suitable to detect the variations in waves, in the other hand, with the frequency analysis students can observe how as the angle of displacement increases, in the frequency appear new harmonic components in wave.

6 Conclusion

The study of physics requires an important abstraction and association of the physical phenomenon with the mathematical formulation that describes it. This description is usually strong in formalisms and deep concepts of mathematics that require long and complex developments for students of introductory courses in physics. In order to simplify the developments, approximations are usually made in developments such as the case of the pendulum for small angles as a simple harmonic movement given its

similarity with the uniform circular movement. However, approximations can induce students to conceptual errors or to consider that the physical phenomenon always has the same behavior under all conditions leading to not associating the phenomenon correctly with the mathematical formulation.

Based on the above, it is extremely necessary to look for other tools that allow a better understanding of the phenomenon and for undulatory phenomena, analysis in the frequency can be a very good visual approximation to the deep reality of the phenomenon analyzed.

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Smartphone Technology Applications for Milkfish Image Segmentation Using OpenCV Library

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Abstract—This research presents the use of smartphone technology to assist fisheries work. Specifically, we designed an Android application that utilizes a camera connected to the internet to detect RGB image objects and then convert them to HSV and gray scale. In this paper, Android-based smartphone technology using image processing methods will be discussed, a digital tool that provides fish detection results in the form of length, width, and weight used to determine the price of fish. This application was created using features provided by the OpenCV library to produce binary images. Three main challenges highlighted during application design including C ++ QT were used to build the user interface, the contour-active method was used to divide and separate image objects from the background, while the clever edge edge method was used to improve the outline appearance of objects. Both methods are implemented on the Android platform and utilize smartphone cameras as an identification tool. This application makes it possible to provide many benefits and great benefits for farm farmers but on the other hand will create technological gaps.

Keywords—Library OpenCV, Citra Segmentation, Android Application, Technology Smartphone.

1 Introduction

Having the best smartphone for various needs is important but still depends on the software or application that is owned according to work requirements. Various mobile applications that can help human work [1], [2] and the very trend right now [3] growing so fast and constantly updated and tends to connect hardware into applications such as cameras, sensors, com-passes, Bluetooth, Wi-Fi to meet user needs [4]. The integration of Mobile device is an innovative process to increase labor mobility and flexibility on the workforce [5] and and caused desktop computing to be replaced by the emerging mobile computing technology [6].

Mobile application innovation is now moving towards the digitalization of processes that aim to create quality [7] and the most interesting thing is image processing

technology mobil based [8] to detect product quality through image objects [1], [8] besides also used for visual identification and video analysis [2], [9] and used as solutions to help people with color blindness [10]. Various cloud-based mobile computing applications have been developed and presented to users such as, cellular learning, cellular health services, mobile games or industrial needs [5] The need for mobile technology with the ability to image segmentation in the freshwater fish industry is used to identify the quality and type of freshwater fish [11]. This research succeeded in designing an image segmentation technology based on an android mobile application using the active contour method. [12], [13]. The technology proposed in this research is a form approaching the digitization process used computer vision and image processing to segmentation. The OpenCV library is used for application development because it can work on various operating systems and across platforms [14] as well as having complete algorithms and functions for image processing function [8] besides that it has been implemented in several image processing projects [4], [14]. The focus of this research is to look at and demonstrate the utility of an android mobile application and find out how efficient an image processing application can be used to check and assess the benefits of a product.

1.1 OpenCV and platform android

OpenCV Library (Open Computer Vision) is a library used primarily for image and video processing needs so that it can extract information in it. The OpenCV library has 2500 algorithms first introduced by the Intel Research initiative to advance CPU-intensive applications in 1999. OpenCV library can be built with a variety of sump as programming such as C, C ++, Java, Python that massing one has sample code for real-time computer vision and support a variety of platforms such as windows, Linux [4], Mac OS, iOS and Android [15]. OpenCV Library Version 2.2 is the first version that can be built on the Android operating system and in version 2.3.1 has been equipped with a program code for image processing on the Android system [4]. The data type in OpenCV is IplImage derived from the word Intel Image Processing Library which is the main image structure in OpenCV [8]. Much other research carried out by using OpenCV to create a system capable of capturing, identifying and analyzing the features in the image [14] such as face detection and tracking features that use a combination of Java and C ++ to build programming code [4]. Basically, the image detected will be converted to binary values and OpenCV provides a library for doing this like inRange, threshold, Adaptive Threshold, Canny and others to make binary images to grayscale or color.

Building image processing applications on the Android platform requires an Android software Native Development Kit (NDK) as an API (Application Programming Interface) tool [16]. NDK has a set of features that help use C ++ and C programming codes.

1.2 Citra RGB and HSV

The digital image is defined as a function f (x, y). The value f represents the value of the gray degree of the object at points x and y, while (x, y) is the position of the pixel where the value is x represents the row number while they value represents the column value [17]. RGB (Red, Green, Blue) imagery consists of three image fields where each color has a value of each pixel [18]. Object Pendetksian dap at done in several ways one of them by way of color-based HSV. HSV Digital Image defines color in the terminology of Hue (True Color), Saturation and Value (Color Brightness) [19] HSV image contains colors that n is equal to that captured by the human senses. While the colors formed by other models such as RGB are a mixture of primary colors [17]. RGB images are more dominant in the original image of an object.

Building image processing applications on the Android platform requires an Android software Native Development Kit (NDK) as an API (Application Programming Interface) tool [16]. NDK has a set of features that help use C ++ and C programming codes.

Fig. 1. RGB type Digital Image

1.3 Thresholding technique and binary image segmentation

Threshold is a process segmentation image to change the grayscale image [20] that will produce a binary image [20]; [21] and has two possible pixel values, namely the intensity value of the image that is more than or equal to the threshold value of 1 (white or foreground) and if it is less than the threshold value or value 0 (black or background) that you want to remove . Each pixel in the binary image has a size of 1 Bit. Processing binary images are done by refer to (1).

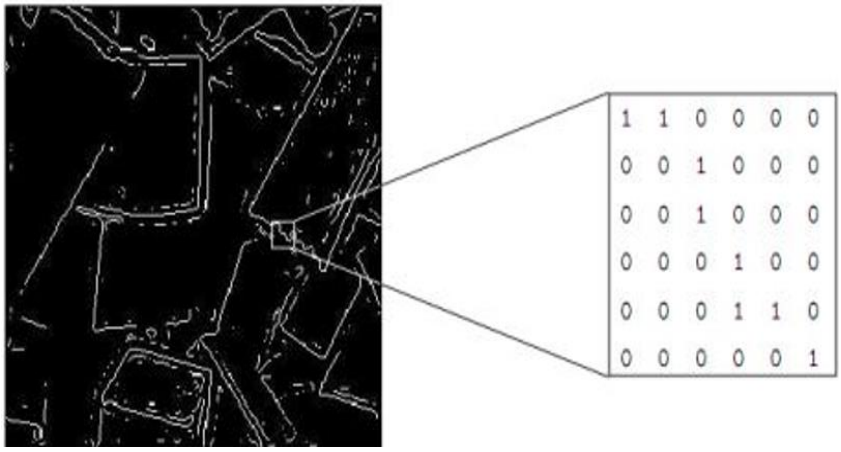


Fig. 2. Digital Image and Binary Value

Processing binary images with refer to (1) and in floating-point form done with refer to (2):

$$I_{Bin}(x,y) = \left\{ \frac{0 I_{BW}(x,y) < T}{255 I_{BW}(x,y) \geq T} \right\} \quad (1)$$

$$I_{Bin}(x,y) = \left\{ \frac{0 I_{BW}(x,y) < T}{1 I_{BW}(x,y) \geq T} \right\} \quad (2)$$

Where :

I_{Bin} (x,y) = Binary pixel value at point (x,y).

I_{BW} (x,y) = Pixel value at point (x,y) in a grayscale image.

T = Threshold value

An image with a grayscale type and model in the arrangement of pixels consisting of rows and columns shown in figure 3. Each pixel has a degree grayscale with a numerical value in the range of 0 (Black) - 255 (White), and each pixel has a size of 8 Bit or 1 Byte. With such a digital image symbolized as a matrix of pixels with a value of 0-255

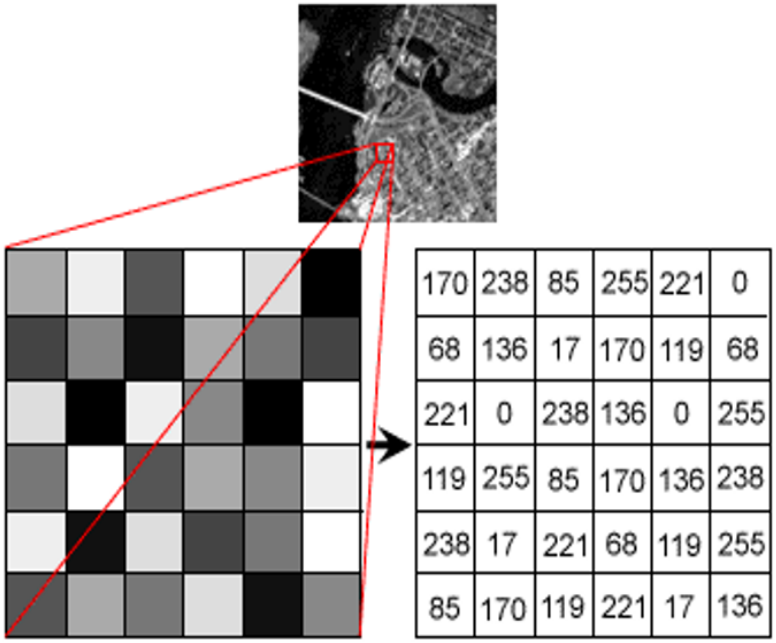


Fig. 3. Grayscale Type Digital Image

2 Method

In this section, we will introduce the proposed scene image detection system. We use the Android platform because it is free and open source and is widely used to develop mobile applications [10]. This research uses Java and C ++ as the basis for programming code. To create an An-droid application, the C ++ section will be built first by using the Native Android Development Kit (NDK) to improve application performance, while the OpenCV library is used for processing image coding, all programming code is built on the operating system Windows then converse I to APK for Android smartphone applications and uses the camera as a detection tool. The program is run by using the camera on a smartphone [6]. Object samples that will be detected in this study are banding and the results of image processing will display information about weight estimation and price calculation. To get the best object detection results, the minimum Android specification uses version 17 with 1 GB of RAM and a 5 Megapixel Camera. The system workflow in this application can be explained, see Figure 4.

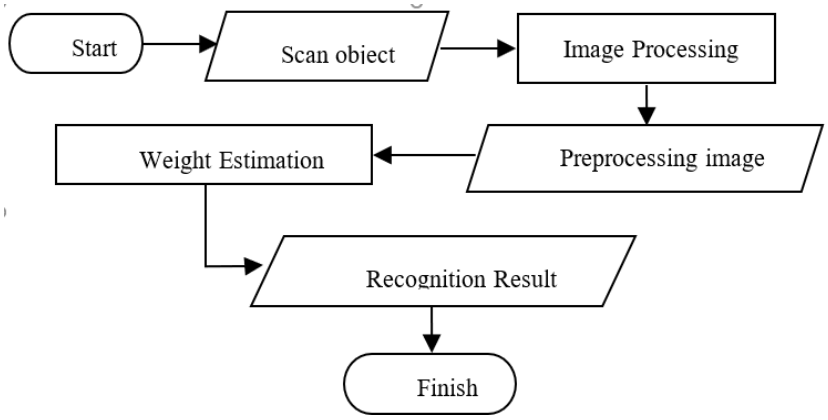


Fig. 4. The Flow of Each Image Processing Level

The first stage, the camera on the android anchor will detect the object and then use it as an input image after the input image has been successfully captured, the next step is *preprocessing the image.* [20], that is, first - the first image with the JPG type and the original color model obtained from the camera is RGB will be converted into two color models namely HSV and Grayscale. Process conversions are explained as follows. Conversion the image from RGB to HSV is done by using the *In Range* feature in the OpenCV library, this is a color-based detection process after which color segmentation is done, this function uses refer to (1) and (2). to get a *pixel* value binary at each color point, then operating a morphological image is a process to reduce noise and also to eliminate black holes on objects. The next stage of detection contour on objects using *canny edge detection* to identify the boundary edges of objects, the data contour then stored in *an array* a *rotatories'* (*rectangle* accompanied by rotation), this process has a detection parameter or *pixel* value. Meanwhile, image conversion from RGB to Grayscale is also carried out by taking detection parameters from the database. Thresholding technique the image on an object applied to be able to distinguish and separate the objects needed color white (foreground) and black background objects that must be removed (background) [21]; [22] so that it produces a binary image [21]. For basic operations thresholding OpenCV function is used cv:in Range and u to reduce noise the morphological operation is done so that the contour of the object detected in binary imagery is obtained. Next, detect the bounding box i.e. the system will draw a bounding box that shows the width and length of the object to be measured using the find Contours () function that is available in the OpenCV library. This rectangular bounding box is the area found in the contour stage image. This process is done by using functions find Contour () in the OpenCV library, the biggest contour in binary imagery will give a value of length and width in pixel units. The final stage of image preprocessing is performed to the pixel value conversion unit centimeter, Inch and Kilogram. So that the weight of the detected object can be known. The flow of each image processing level is summarized in figure 5.

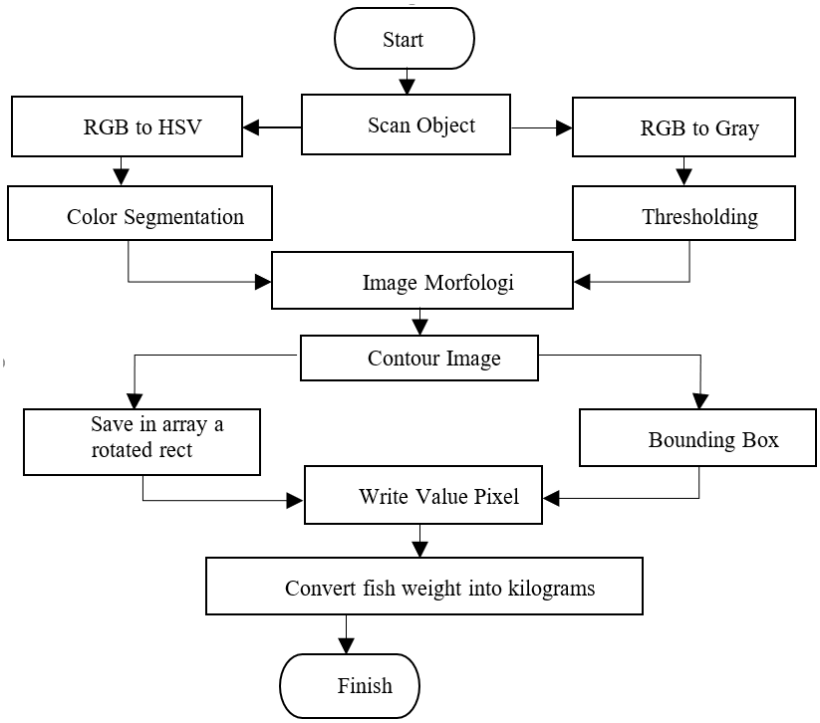


Fig. 5. The Flow of Each Image Processing Level

Camera connection to the internet allows applications and services to be used when users are everywhere [6] Before android smartphone application is really used, we do camera calibration to locate and track detection patterns to be performed by the system, calibration carried out on a large light intensity affects the image capture. Calibration is done with the following equation

$$f = \frac{P * D}{W} \tag{3}$$

Where :
F = Camera Focal Length (pixel)
P = Object Lenght in camera (pixel)
D = Distance object from camera (cm)
W = Actual object lenght (cm).

3 Result

Image processing application built on Android The smartphone successfully identifies the object as an area of digital image processing. The object contained in the image is a pixel location which is considered to have a difference in image intensity

and is marked as a boundary box (Bounding Box). Bounding box will give the value of the length and width of the fish object and then calculate the weight estimate.

3.1 Pseudocode programming models on device

Finding contours is one of the most important stages in image processing. Contours are the result of a threshold process that forms an area segment and appear as a bounding box that is, a rectangular box follows the edge of the object detected. Some of the relevant OpenCV functions are as follows:

```
  /// Find contours
  findContours(threshold_output, contours, hierarchy,
CV_RETR_TREE, CV_CHAIN_APPROX_SIMPLE, Point(0, 0) );
```

To convert RGB to Grayscale color, the following functions are used:

```
  /// Load source image and convert it to gray
    src = imread( argv[1], 1 );
  /// Convert image to gray and blur it
   cvtColor( src, src_gray, CV_BGR2GRAY );
   blur( src_gray, src_gray, Size(3,3) );
```

As for the color conversion from RGB to HSV used function as follows:

```
  //Convert Image to HSV
  cvtColor(frame,hsv,CV_BGR2HSV); in
Range(hsv,Scalar(h_min,s_min,v_min),Scalar(
  h_max,s_max,v_max),hsv);
  imshow("hsv",hsv);
```

The detection results will be stored in the SQL database system to become calibration data. The program method for storing new detection parameters.

```
  if(!db.cekDataDetector()){
    db.addParameterAutoDetect("0","0","56","255","255","2
55","time");
  }
```

The detection results will show the length and width of the object in the centimeter unit, the value will be converted to Inch then weighted using the following function

```
  // conversion cm to inch
    double inch = cm / 2.54;
  // Formula to find fish weight.
    B = (L * (G * G) ) / 800;
  // return the contents of the result variable
```

The Android smartphone application built has a control panel for selecting HSV colors by determining the minimum and maximum HSV color values. The program code used is as follows:

```
  //Create a trackbar on the HSV frame
  inRange(hsv,Scalar(h_min,s_min,v_min),Scalar(h_max,s_ma
x,v_max),hsv);
  createTrackbar("H_MIN: ","hsv",&h_min,255);
    createTrackbar("H_MAX: ","hsv",&h_max,255);
    createTrackbar("S_MIN: ","hsv",&s_min,255);
    createTrackbar("S_MAX: ","hsv",&s_max,255);
    createTrackbar("V_MIN: ","hsv",&v_min,255);
    createTrackbar("V_MAX: ","hsv",&v_max,255);
```

The implementation of the program code that has been made will be the rule in the device used. To see how the device works, the system framework is presented in Figure 6. The system framework shows the object detection process and then converts the color from RGB to HSV and Grayscale to get a line that produces values of length and width in centimeters. This value is then in conversion to Inch unit and kilogram (kg) to get a weight value. So that the end result of processing this image is a value of the weight of an object, in this case, is milkfish.

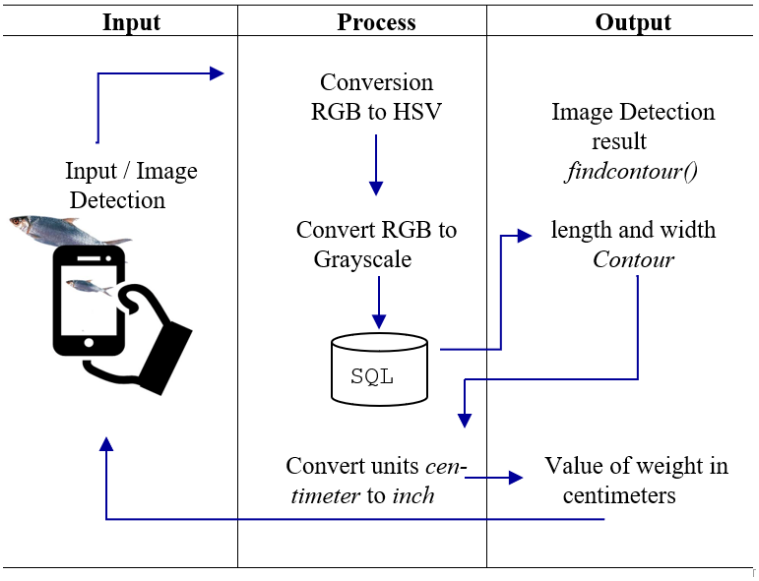
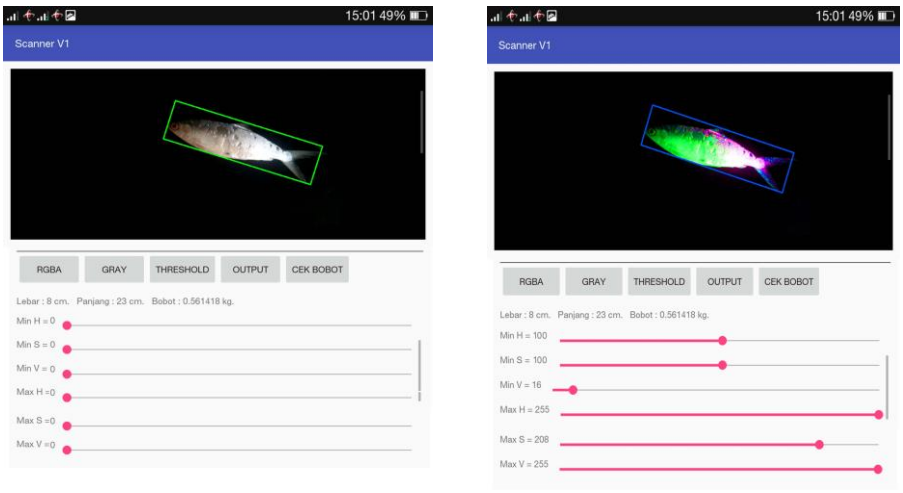


Fig. 6. System Framework of Android Smartphone

3.2 Implementation

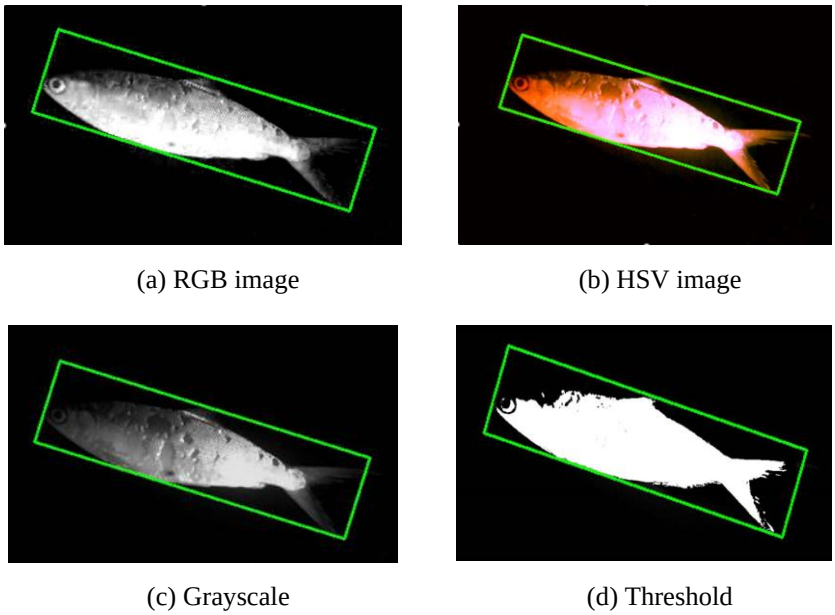
Android-based detection system modeling smartphone has an interface for displaying images of milkfish captured by cameras and pieces setting minimum and maximum HSV values and Grayscale. The home interface image is presented in Figure 7.



a) Normal Image Detection b) Conversion to HSV

Fig. 7. HSV value conversion settings

Figure 7 is the original image captured by the camera in RGB format with HSV = 0, while figure 7 b shows image conversion from RGB to HSV. The Android smartphone application has a control panel that uses the *Trackbar*() function on OpenCV, this serves to select or adjust the color of HSV both minimum and maximum. The value of *h_min* = 100 , *h_max* = 255, *s_min* = 100 , *s_max* = 208, *v_min* = 15 , *v_max* = 255 . The value of *H* (Hue) represents the color, *S* (Saturation) represents the dominance of colors and V (Value) represents the level of brightness [19]. This value gives a reddish-green color. If the saturation value is 0 then it is not colored at all or between black and white. In the RGB color type, the HSV value can be seen in the component with the lowest value (min) and the highest value (max) or in other cases it can be called the lower and upper limit values. The color obtained from the HSV conversion will not affect the length and width and the weight produced.



(a) RGB image (b) HSV image

(c) Grayscale (d) Threshold

Fig. 8. Result of the RGB / HSV / Gray / Threshold Image Type Conversion

Figure 8 shows the results converting the color of the object from the original the green line around the object is the *bounding box* created with the OpenCV *findContours ()* library, this line will determine the length and width of the fish object detected. To obtain the contour value, you must consider two contours, one inside and one outside. Because the contour line with pixel width is greater than one, then the contour value in using the *Inner* function will be used in the OpenCV library.

3.3 Advantage

Android smartphones with image processing capabilities to get the weight and price of milkfish have provided new and practical ways for fishermen or pond farmers to see the weight of fish without having to use scales or traditional methods. In addition, the application provides a list of products or types of milkfish along with the weights and prices that have been detected previously. Android smartphone application.

3.4 Limitation

The application cannot be used for a large number because it has not considered the efficiency and required power consumption. Autofocus on the camera does not work well so that the distance shooting still affect the results of the detection, in addition, design user interface application design has not been based on the concept of user experience so that it becomes familiar.

4 Conclusion

Image processing methods that exist in the OpenCV library have worked well on Android devices. The capacity of performance and many functions of the algorithm the one in the makes it easier for a war on android apps. In addition, the image processing method that has been entered into the smartphone android device has succeeded in detecting objects and digging up information that exists on these objects as the purpose of this study. Even so the system that was built and the Android smartphone device as a detection medium has not considered the power consumption needed so it is not possible to control all objects in large numbers other than that the thresholding technique used on an image, is still strongly influenced by uneven lighting or image factors blurry which causes the histogram can not be partitioned properly so that it does not give satisfactory results. To anticipate some of the deficiencies that exist, further research can be done by increasing the flexibility and sensitivity of the detection camera and better calibration.

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ASDSR: An Adaptive Stable DSR Routing Protocol for Mobile Ad-hoc Networks

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Abstract—The process of finding a route between the transmitter and the receiver node in the Mobile Adhoc Networks (MANets) is a renewed issue that is becoming more and more interesting to the researchers as this type of networks grow and expand. The dynamic nature of MANET and the limited capabilities of wireless nodes in terms of memory size and battery charge are the most important obstacles to the routing (path-finding) process between nodes. In this research, we introduced a new protocol based on the well-known DSR protocol. The proposed routing protocol adds a mechanism to control the RREQ Flooding process; this aims to reach more stable routes while reducing the overhead of routing process caused by link breakage between nodes, and reduces the overhead of network flooding with RREQ messages with each attempt to find a path. In this proposed mechanism, RREQ messages are sent to subset of the devices that are adjacent to the transmitter node, this selection depends on a stability evaluation criterion calculated based on three weighted factors: the speed of the node, the out-degree value (the number of adjacent nodes), and the number of tracks stored in the nodes' memory. The proportion of devices selected is automatically changed adaptively to ensure the achievement of the expected throughput for this network. The proposed protocol was tested using simulation where results showed that ASDSR proved an enhancement in route stability about (0.13), and a decrease in the number of deleted routes by (9%), while maintaining the expected packet delivery ratio of the original DSR by about (0.86).

Keywords—MANET, Routing, Route stability, DSR

1 Introduction

Mobile Ad hoc network, a term considering networks in which nodes are free to move from location to another while there is no infrastructure to connect and manage

transaction between them [16]. Due to its lack of underlining infrastructure, nodes connect with each other in a decentralized manner, where each node expected to participate in the routing process of transmitting messages from source node to the destination node and they are assumed to work collaboratively while routing messages in order to accomplish an accepted level of service [3].

Finding an efficient route between two requires a routing process that depends on a specific routing algorithm. The routing algorithms is a set of rules that are responsible for finding the more appropriate route between two nodes in a network according to specific efficiency metric. Different proactive and reactive routing algorithms are introduced in the literature, where routes between two hosts may consist of many hops through other hosts in the network. Proactive protocols [7, 13, 18, 22] suggests storing routing table in each node's memory resulting in minimum transmission time while sending packets since the route already known, but it consumes mobiles storage capacity. On the other hand, Reactive protocols [12] [27] find routes on demand; if the node wants to send packet, it will search for the route and store it in its memory. Reactive protocols give better storage utilization while there is a delay in the process of searching for suitable route.

Due to the nature of MANET, link breakage between nodes occurs when two adjacent nodes go far from the range of each other because of nodes mobility and frequent changes in their locations. This is considered one of the most expected problems in mobile ad hoc networks [25]. Hence, a stable, efficient, and less overhead routing protocol is needed to facilitate finding stable routes from source to destination node.

1.1 Dynamic source routing protocol (DSR)

DSR is one of the reactive routing protocols in MANET, DSR relies on searching for the route once it is required [27]. This process involves two stages: route discovery; which includes flooding of a packet called Route Request (RREQ) message that passes through the network looking for a route to the destination node. The second stage is route maintenance, which begins when the communication between two nodes is interrupted, and then a Route Error (RERR) packet is sent by nodes surrounding the failed link to inform other nodes about this change. Many challenges lie in the process of routing in MANET, such as, the limited nodes storage and battery, the burden of overflow of messages during the process of establishing the route, and the continues movement of network nodes causes frequent interconnection of nodes. In DSR, if node ni want to send a packet to node nj the method is illustrated as follows:

1. Node ni will search for a route in its memory which leads to node nj. If there is a route, the message will be sent directly through the saved route, otherwise, step2 will be performed.
2. ni will try to find the path that fulfill its demand. The process of finding route starts by generating a special message called Route Request (RREQ), this message contains information about the source ni and destination nj of the transmission and

additional information about the intermediary nodes passed-through by this RREQ in order to keep track of the found path.

3. The RREQ message will be broadcasted to all surrounding nodes. If node ng received the RREQ, and it is not the desired destination, it will re-broadcast the RREQ again to its neighbors. The process continued until RREQ received by the destination node nj
4. If nj received the RREQ, then nj will generate another message called Route Reply (RREP) message. RREP will contain the same information about ni and nj from RREQ just received.
5. RREP will be sent back through the found route from one node to another until reaching the sender node ni.
6. The initiator node of RREQ and any node within the route will save the new discovered route to nj in its cache memory.

Link breakage between nodes occurs when two adjacent nodes go far from the range of each other because of nodes mobility and frequent changes in their locations. This is considered one of the most expected problems in mobile ad hoc networks [25]. In DSR, if link breakage occurs, each node realized the failure will generate a Route Error (RERR) message and broadcast it over all nodes to delete any route depends on this failed link.

Fig1. shows an example of using DSR in the process of broadcasting RREQ message starting from the sender node (N1) searching for a route to a destination node (N21). All neighbors of (N1) will receive the RREQ message (N2,N3,N4,N5,N6), unfortunately, none of them is the desired recipient, as a result, each of the neighbors have to participate in the routing protocol and re-broadcast the message to its neighbors. If a node received the same RREQ another time it will not re-broadcast it. This process continues until reaching (N21). You many notice that there are many paths guide to the destination node (N21). The first RREQ received by (N21) will be considered as the desired route and then node (N21) in its role, will generate Route Reply Message (RREP) and send it back through the found path until reaching the sender N1. During this process, each node inside this route will save the route to (N21) in its memory. Here, (N1) will save the route (N3, N10, N22, N21), (N3) will save a route to node (N21) too, which is (N10, N22, N21), and (N10) will also save the route (N22, N21).

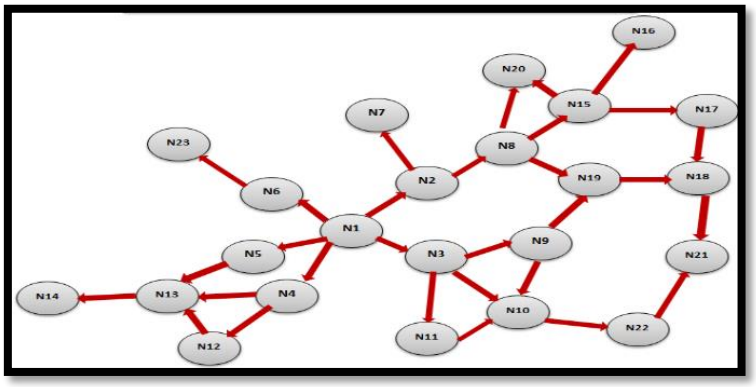

Fig. 1. DSR broadcasting process.

1.2 Related work

In this section we will describe techniques and directions used by other researchers in the area of routing protocols in MANET. Our proposed method is actually based on DSR routing protocol; therefore, we will explore some of the existing DSR enhancement techniques observed from previous researches.

Since the battery limitation is one of the most challenges in Ad-Hoc networks, [19] proposed a route discovery mechanism taking into account nodes' energy consumption in order to increase node life time. When a neighboring node received the RREQ message through a route discovery process, it will add its node ID in the request packet and update its total energy field in the RREQ and then rebroadcast the RREQ message. The simulation result showed that their Modified DSR protocol achieved less energy consumption when compared to the original DSR protocol.

[5] Proposed an enhancement to the route discovery process considering nodes energy consumption for transmission and reception of single packet rather than considering minimum number of hops in the network. When a destination node receives the RREQ message, it will send the RREP message via only nodes having less energy consumption. The authors simulate their ideas and prove its effectiveness regarding the average throughput and energy consumption compared with DSR and other routing protocols. DSR comparisons showed an enhancement about 0.48 achieved in nodes' energy consumption, and about 0.75 enhancements in network throughput for 50 nodes test.

In [9], a multipath energy aware routing for wireless ad hoc network was presented. All possible paths between a source-destination are stored, the destination replies to all route requests (RREQ)s that arrive, and the source stores all the paths of received route reply (RREP)s. The paths are ordered by an energy-based metric. An enhancement about 0.10 in achieved in packet delivery ratio showed by the simulation, while network overhead incremented nearly by 0.01.

[6] Proposed an enhancement on a DSR protocol in order to increase network throughput by increasing the number of maximum retransmission requests size. The authors performed this by setting the value of the maximum retransmission parameter to 32. From simulation, throughput results are analyzed showing that the initial value of throughput is increased by 8.08% of updated DSR and final value is increased by 4.43%. The sample mean value is increased by 5.85%.

In [28] an algorithm was suggested to reduce the flooding of RREQ packets in the network. The basic idea states that while route discovering process, the node receives a RREQ packet will check the following parameters: its own residual battery, received signal strength, and speed. If the defined thresholds for the node for these mentioned parameters satisfy, then the RREQ packet will be forwarded in the network, otherwise, the RREQ packet will be discarded. Evaluation method using Qualnet simulator showed that it results in an increased throughput and average residual battery of the node and decreased the average end to end delay and jitter.

In [8], the authors developed a caching strategy to reduce the flooding overhead by avoiding route discovery as much as possible. In their strategy, the available path is preferred rather than the optimal one; nodes update their cache quickly to minimize end-to-end delay for short-lived traffic by using active packets. The correct information in caches allows to speed up the route discovery and even to avoid it. The packet delivery ratio of the proposed strategy is 99%, which indicates that their proposed approach successfully updated nodes caches and significantly reduced the chance of packet loss due to a route failure.

[2] Proposed a modified DSR termed as Mobile internetwork broadcast infrastructure technique (MIKBIT). In this approach, broadcasting aims to reduce the high overhead involved in flooding while route discovery. Simulation showed an increase in throughput by 130%, and the average end to end delay is less by 90%, jitter is reduced and packet delivery ratio is improved than that of DSR protocol.

In [26] authors applied the Genetic algorithm and Ant Colony swarm intelligence method on DSR protocol to find the optimal path taking into account the misbehaving nodes in the network since the selfish and incapable nodes are some of the causes of network low performance. In their proposed algorithm, any path from the source node to the destination node is a feasible solution; the optimal solution is the shortest one. Another research by [14] also proposed an ant-based hierarchical routing protocol that uses Ant colony optimization algorithm to meet the application-specific Quality of service requirements of heterogeneous traffic generated by the source nodes. Simulation results approved that their protocol outperforms other protocols in terms of energy efficiency, end to end delay, and packet delivery ratio.

[11] Proposed an optimized DSR routing protocol with ant algorithm. Evaluation and Analysis for the proposed approach was done with various scenarios. DSR ant has 48% smaller delay, 1.37 times smaller hop count, and throughput up to 3.6 times larger than the standard DSR, but DSR-ant has routing overhead 58% larger than standard DSR.

[1] Used clustering approach to select only a subset of nodes that need to forward the packet to (RREQ flooding) through route discovery process. This approach aimed to reduce network overhead by eliminating the unnecessary flood. Simulation results

showed that their optimized DSR algorithm enhances the packet delivery ratio by minimum of 20% and reduces the RREQ flooding by a minimum of 30% by integrating passive clustering with DSR, the number of unnecessary flooding of RREQ packet reduced by minimum 30% in mobile ad hoc networks. The number of Route Errors (RERR) was reduced by 17 %. The packet delivery ratio was improved by a minimum of 20% as well.

[15] Proposed an improved DSR protocol which adopts adaptive routing shortening method through introducing time parameters; routing quality is decided by routing survival time. Adaptive automatic routing shortening can produce routes with small amount of hops and guarantee remaining survival time of new route. The performance of this method compared with the DSR protocol using simulation, and enhancement is noticed in the throughput metric and the delivered packets ratio, while there is a bit increase in the delay metric.

[17] Proposed an algorithm for modifying DSR protocol, which is referred to as Modified DSR (MDSR). A memory management algorithm also proposed; in which packets are transmitted with minimum required energy. Results reveal that this algorithm achieved 47% less number of control packets in the networks of low mobility and 4% less number of control packets for the network of highly mobility nodes.

[4] Proposed a QoS-based (Quality of Service based) protocol to improve the performance of the DSR protocol and enhance the reliability of the network. This protocol considered the QoS of the paths in route discovery process in which the path with highest QoS value is selected. The QoS function depends on the factors: the available bandwidth of a node, connectivity level, distance ratio and velocity ratio. Using simulation, nearly 0.40 enhancements was achieved in packet delivery ratio metric.

In our proposed ASDSR, the aim is to find the more stable route while decreasing routing process overhead by introducing an enhancement to the DSR algorithm. During route discovery process, flooding is done by selecting a subset of neighbor nodes to send RREQ message to them rather than broadcasting it to all network nodes. This selection is performed according to a computed stability value depending on three weighted factors: node speed, number of its out-going links, and the number of stored routes in its memory, weight values depends on network requirements. Routes found and stored in nodes' caches will be stable as much time as possible due to taking nodes stability into account during route construction. The remaining of the paper is organized as follows: in the next section a discussion of the proposed ASDSR and its algorithm is presented, then we described the stability function and the evaluation method of our enhancement followed by results discussion and analysis. At the end of the paper a conclusion is presented.

2 The Proposed Adaptive Stable DSR Protocol (ASDSR)

In DSR protocol, when an initiator node starts route discovery stage, it will send the control packet RREQ to each neighbor node. The process of flooding RREQ

through the network and rebroadcasting it will generate routing overhead through the network which will affect nodes energy-consumption and the overall performance of the network. Unfortunately, this process will be repeated for each time a new route is needed. Thus, frequent link breakage makes this type of flooding is a main concern.

Our proposed ASDSR protocol aims to find a more stable route while decreasing route discovery overhead on the network. The following steps illustrate how the proposed ASDSR protocol behaves when node n_i wants to send a packet to node n_j that are depicted in figure 2:

Step 1: Checking cache memory: Node ni will search for the route in its cache memory. If a stored route found, the message will be sent, otherwise, step2 will be performed.

Step 2: Generating RREQ message: Node ni will try to find the path that fulfills its demand. The process of discovering a route starts by generating a special message called Route Request (RREQ). This message contains information about the source ni and destination nj of the transmission and additional information about all intermediary nodes that received and re-transmit the RREQ during the routing process in order to keep track of the found path to the destination node.

Step 3: Flooding RREQ based on stability: Node ni reads the stability value for each neighbor node. Assuming each node in a network calculates the stability value periodically and make available to other nodes. The RREQ message will be send to a subset of neighbor nodes that have greater stability values. If node ng received the RREQ, since ng is not the required destination, it will re-send the RREQ again to a subset of its neighbors according to their stability values. The process continued until RREQ received by the destination node nj.

Step 4: Reach the destination: If nj received the RREQ, then nj will generate another message called Route Reply (RREP) message that contains the same information from RREQ just received.

Step 5: Sending back the RREP: RREP will be sent back through the found route from one node to another until reaching the sender node ni.

Step 6: Saving a rout: The initiator node of RREQ and any node within the route will save the new discovered route to nj in its cache memory.

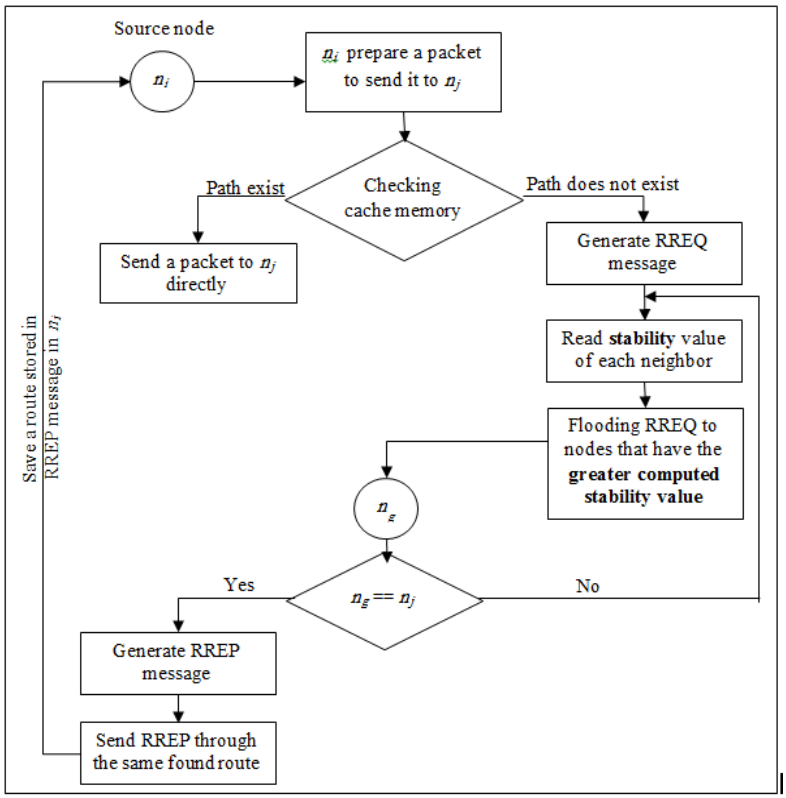

Fig. 2. ASDSR routing process

Note that sending RREQ to just a set of neighbors will shorten the process and reduce RREQ flooding (*s* in the figure denotes the computed stability value for a node). The selection of these neighbors related to a computed stability value; for example, node (N1) sent the RREQ to node (N2) and node (N6) and node (N4) because they have the largest stability values among all N1 neighbors. The route found may differ from that found by the Original DSR (refer to example in section 1.2). According to Figure 3; the route found is not the shortest path (N2, N8, N19, N18, N21). This path has a length of (5 hubs) compared with (4 hubs) path found before, In this protocol, we can achieve our goal of finding routes that stay for longer duration while decreasing the routing process overhead, the shortest path is not our goal here.

Figure 3show the process of searching for a route from the sender node (N1) to the recipient node (N21).

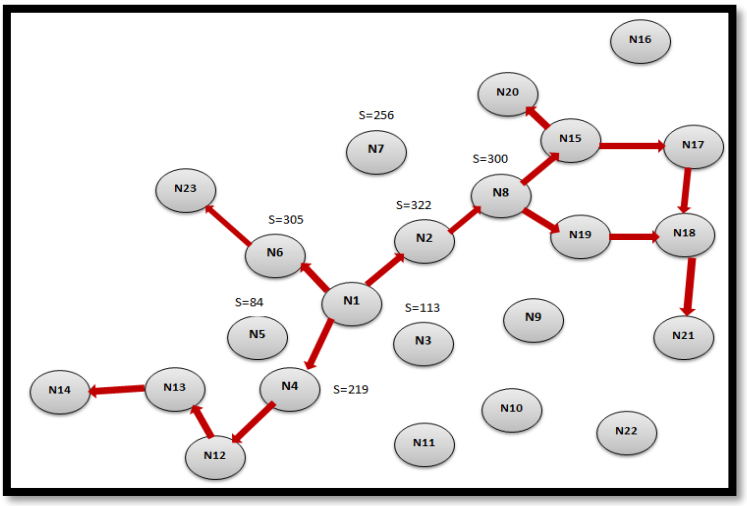

Fig. 3. ASDSR RREQ message flooding based on stability

In the proposed ASDSR a dynamic percent of neighbor nodes will be selected each time to send RREQ message to them; this percent is adaptive with a defined threshold for the accepted average for packet-dropping percent. If the percent of the dropped packets exceeded this threshold, the percent of neighbors that will receive the RREQ message will increase by 0.10 until the average for packet-dropping rate decreased and ensure maintaining an accepted network throughput. To determine this threshold value, we had studied the performance of the original DSR, we noted that the percent of dropped packets wasn't exceed (0.14), therefore, we selected a threshold value which is (0.14) as an accepted value for the average packet-dropping rate, such that the total performance of the network should not exceed this value. Figure 4 shows the changes in the dynamically determined neighbors' percent value during a simulation of 50 time slots.

As noticed from the figure, neighbors selection percent start from (0.50), at time slot (15), the percent start to increase slightly to indicate that the number of dropped packets start exceeds the defined threshold value, it reaches (1) at time slot (20) and returns to decrease at time slot (22), and thus stays increasing and decreasing to ensure an acceptable network throughput.

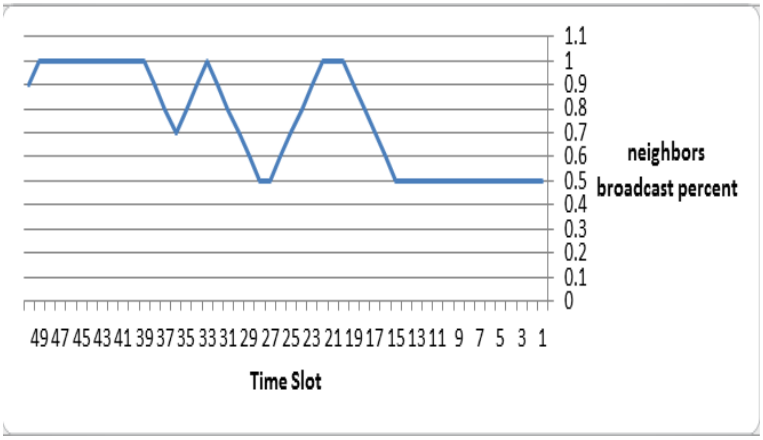

Fig. 4. Neighbors Selection Percent in ASDSR

3 Stability Function

Node stability value is an indicator to how much this node is trusted to establish a long-life route rout passing through it. In our proposed approach we used three main factors as indicators to nodes' stability; node speed, out-degree value, and the number of stored routes.

Node speed, the first factor, is the most critical factor which affects route stability, when node moves in high mobility speed it will not be effective decision to create a route passing through it, since the probability of link breakage will be very high. The second factor is the out-degree value; this factor indicates the number of out-going edges (number of neighbors) for this node. Neighbor node with higher number of out-degree value is more dependable compared with isolated nodes; a node with low-speed and few number of surrounding nodes will not be a good choice for route selection. The third factor is the number of stored routes in nodes' cache memory; the node with more routes stored in its cache memory is considered as an active node and has a strong social network with other nodes, then it will be a good choice for route construction. Stability values will be computed according to Equation (1):

$$S_{ni} = \alpha\,(M - SP_{ni}) + \beta\,(O_{ni}) + \gamma\,(R_{ni}) \quad (1)$$

where S_{ni} is the stability factor value computed for node n_i. M is the maximum speed value defined for nodes movement in the simulator**.** $\mathbf{SP_{ni}}$ is the speed of node n_i. O_{ni} is the number of outgoing links for node n_i. R_{ni} is the number of routes stored in node n_i memory. α is the weight for the node speed factor, β is the weight for the out-degree factor, and γ is the weight for stored routes factor, where the summation of all of these weights equals 1 as shown in Equation (2):

$$\alpha + \beta + \gamma = 1 \quad (2)$$

The values chosen for the weights α, β, and γ can be determined depending on several network features, such as nodes transition speed (high, low), mobility model, nodes distribution, nodes battery and memory capacities, and many others indicators variables for network state. For the purpose of analysis, we tested our algorithm using several combinations of values of α, β, and γ. Each of these combinations is biased towards one of the three factors as will be mentioned in section 4.

4 The Proposed ASDSR Protocol Modeling

Assume that N represents the set of network nodes N={*ni*,*nj*,….,*nk*} and L represents the set of links between nodes, for example L={<*ni*,*nj*>,<*nj*,*n*k>} if there is a direct link between *n*i and *n*j and a direct link between *nj* and *nk*. The direct link indicates that the two nodes are in the transmission range of each other and thus they can communicate directly and send data without requiring any hubs over intermediary nodes. ∀*n*∈N, it has properties such as its position, speed, transmission range, movement direction, and stability value. ∀***l***∈ L, ***l*** connects two nodes (ex, *n*i and *n*j) if the distance between *n*i and *n*j less than or equals nodes' transmission range. We call *n*i and *n*j adjacent nodes and the link ***l*** incident to the nodes *n*i and *n*j.

In MANET, sending data between nodes occurs all the time. If node *n*i want to send data to node *n*j, then *n*i is called the initiating (transmitter) node and node *n*j is called the terminating (receiver, recipient) node The sequence of edges (links) connecting intermediary nodes from *ni* until reaching *nj* is called the "path". In a path, the number of included edges represents the "path length" between *n*i and *nj*, the path relation between *n*i and *n*j is defined as: *p*(*ni*,*nj*), if there exist a path from *n*i to *n*j. Minimal path length between *ni* and *nj* is the path which involves the least number of edges, in this research we are not interested with finding the shortest path; instead we are looking for the more stable path.

Links between nodes are transitive, such that, If *p*(*ni*,*nj*) exists, and the distance *d*(*ni*,*nj*)!=0, and *p*(*nj*,*nk*) exists and *d*(*nj*,*nk*)!=0, this infers that there exist a path between *n*i and *nk* *p*(*n1*,*n3*) where *d*(*ni*,*nk*) != 0. If ∀*ni*,*nj*∈N, ∃*p*(*ni*,*nj*), then G is a connected network. In real mobile networks we cannot ensure fully connectedness between nodes all the time due to nodes mobility behavior.

In our model the broadcasting graph G\ is actually a sub-graph from the actual network graph G, such that G\= (N\,L\) where N\ ⊂ N and L\⊂ L. ∀ ***l*** =<*ni*, *nj*>, ***l*** ∈ L\ if and only if the stability value for node *nj* is within the highest values compared with all *ni* neighbors. For a graph G= (N, L), where N= {*ni*,*nj*,……*nk*}, we represent the direct connections between nodes by using the n * n adjacency matrix adj whose elements *aij* is given by the definition:

$$a_{ij} = \begin{cases} 1: & \text{if } < ni, nj > \in L \\ 0: & \text{otherwise} \end{cases} \quad (3)$$

4.1 Simulation and analysis

MANET in its nature is continues system, where the state variables that describe the system (such as mobile nodes locations, speeds, links between nodes…) changes during the time, link failure occurs when nodes get outside from the coverage area of another node. In order to study the system as it evolves over time and collect statistical variables that evaluate our proposed ASDSR, simulation experiments were performed.

According to the definitions in section *B*, we built a continuous stochastic simulator for Mobile Ad-hoc Network using Random Walk (RW) mobility model. Modeling starts by dispersing nodes through a predetermined rectangular area with dimension (D), nodes move continuously, each time slot, a node may change its speed or direction according to a pre-defined probability. The new speed for node (i) at time slot (t) is chosen by uniform distribution between speed minimum and maximum values [S_{min}, S_{max}], we use the notation ($SP_{ni}(t)$) to denote speed of node n_i at time slot *t*. The direction is chosen randomly by selecting a random angle (Ø) from the interval (0, 2π). During the interval, a node moves with a velocity vector ($SP_{ni}(t)$ cos Ø, SP_{ni} (t) sin Ø). According to this model we built a simulator using (C++) programming language.

We assumed that all nodes wishing to communicate with others, and within the ad hoc network all nodes are willing to participate fully in the protocols of the network. In particular, each node participating in the network should also welcome to forward packets for other nodes in the network. To represent our model by a simulator we assumed that (k) is the number of nodes in the network, where (*n1, n2, n3*, …., k) are the nodes. The new location for a moving node at time slot (t+1) is computed according to the following equation:

$$n_{ix}(t+1)= n_{ix}(t)+SP_{ni}(t)*\cos Ø_{ni}(t) \quad (4)$$

$$n_{iy}(t+1)=n_{iy}(t)+SP_{ni}(t)*\sin Ø_{ni}(t) \quad (5)$$

where, $n_{ix}(t)$: x location of node (i) at time slot (t), $n_{iy}(t)$: y location of node (i) at time slot (t), $SP_{ni}(t)$: speed of node (i) at time slot (t), $Ø_{ni}(t)$: angle of movement for node (i) at time slot (t)

In order to determine if two nodes are adjacent to each other or not, we should determine if the distance between them not go beyond their transmission range, this is done by computing the distance between these two nodes (assume, n_i and n_j) according to the following equation:

$$d_{ij} = \sqrt[2]{\left(n_{jx} - n_{ix}\right)^2 - \left(n_{jy} - n_{iy}\right)^2} \quad (6)$$

When a route deleted from nodes' cache memory due to link breakage, we can compute the average routes stability according to Eq.7:

$$AvgS = \sum_{i=1}^{NR}(\mathrm{RR(i)} - \mathrm{RS(i)})/\mathrm{NR} \quad (7)$$

where: NR is number of routes created during simulation time. RS is the time slot at which the route is created, and RR is the time slot at which the route is removed from the cache because of link failure.

Simulation Parameters values are shown in Table 1; The number of nodes used in the simulation scenarios is 100 nodes scattered uniformly in a rectangular area of dimension Ten meters. Nodes have an equal radio propagation range equal two meters. At each time slot, 10 sessions started between nodes to exchange messages. Nodes move in speed between minimum and maximum values of 0.20 m and 1.50 m/time slot respectively. The simulation runs for fifty time slot every try. Results analyzed from collecting statistical information of a sample of 10 runs.

Table 1. Simulation Parameters

Simulation Parameters Values

Parameter	***Value***
Simulation Time	50 time slot
Area size	10 x 10 m^2
Radio Propagation	2 meters
Minimum speed	0.20 m/time slot
Max speed	1.5 m/time slot
Number of Nodes	100
Number of Sessions each time slot	10

5 Experimental Results Analysis

In this section we will discuss the results of applying the proposed ASDSR protocol compared with the performance of the original DSR algorithm. The proposed ASDSR protocol use three weighted factors as indicators of node stability; node speed, out-degree value, and the number of stored routes. Based on the computed stability value, the ASDSR protocol choses a set of neighbor nodes that will be included the flooding RREQ process. Therefore, we will use four different combinations of the weights (α, β, γ) to these factors to use them in computing the stability values as mentioned in Eq. 1. These combinations were used in the stage of evaluating the performance of the proposed ASDSR protocol as a test values:

1. (OF) Out-degree Factor [20 60 20]: the values for the weights (α, β, γ) are chosen so that the out-degree of neighbor node will have the highest weight; assuming that the node with more neighbors is more likely to result in a stable path passing through it, denoted by Out-degree factor (OF).
2. (SF) Speed Factor [60 20 20]: in this combination means that the major dominant factor in computing nodes' stability value is the node speed; neighbor nodes of lower speed are more trusted to broadcast RREQ message through them, denoted by Speed Factor (SF).
3. (SRF) Stored Rout Factor [20 20 60]: in this scenario, stability value is biased towards node that has more stored routes in its memory since it is the highly active

node and thus it is a trusted node to get stable routes passing through this node, denoted by stored routes factor (SRF)

4. (EDW) Equally distributed Weights [30 40 30]: by giving each factor a nearly equal weight without biasing towards any of them, assuming that all factors are important and affects the process of selecting a stable route.

Simulation of the proposed ASDSR algorithm has been performed on a mobile simulated environment, where nodes move all the time according to Random Walk (RW) mobility model. Simulation results are analyzed and compared with the original DSR protocol in three main dimensions: average route stability, number of deleted routes, and packet delivery ratio.

5.1 Routes stability

We define route stability value as the period of time between two time slots; the time slot at which the route was created and the time slot when it was deleted. Within simulation of fifty time slots, routes stayed for average (14.1) time slots in the original DSR, While they were exist for average (16) time slots in the ASDSR for all weights, an enhancement about (0.125) time slots was achieved by ASDSR. Fig.5 shows the average route stability over 10 runs. Because of the unified values for network state variables, the different combinations of weights resulted in a close stability values, the EDW slightly outperforms the other combinations of weights.

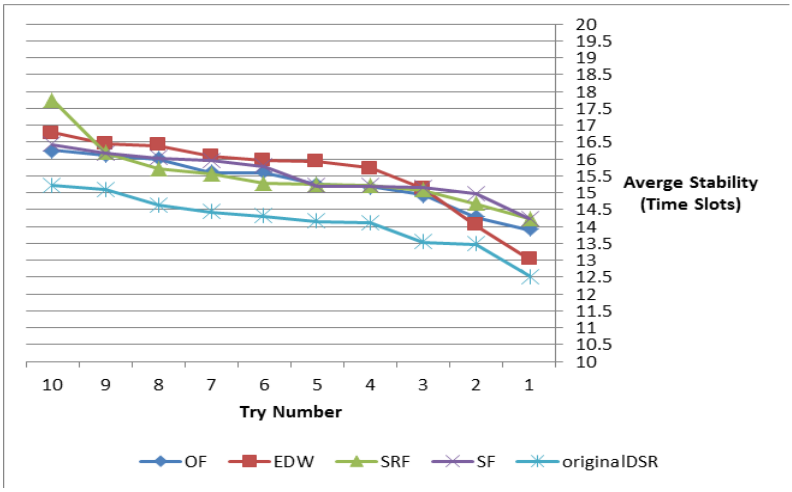

Fig. 5. Average Route Stability Metric

5.2 Number of deleted routes

The results of stability are supported with gaining less overhead caused by the routing algorithm, this could be noticed from the number of the deleted routes, where

the number of the deleted routes were decreased by nearly by 1400 routes in our ASDSR protocol as shown in Fig.6. This enhancement gained although the network environment and mobility model applied including the average link breakage was the same in all simulation experiments and node mobility was random and uniformly distributed.

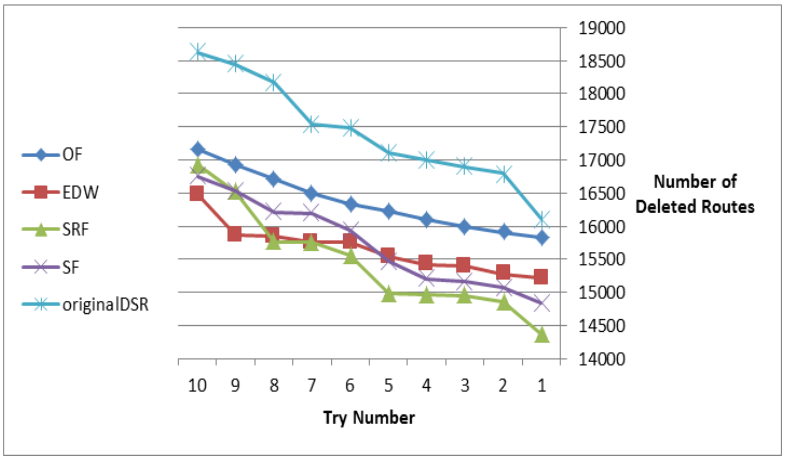

Fig. 6. The Number of Deleted Routes

From a deeper look to the curve, we notice that the number of stored routes in nodes' memory had a significant role in decreasing the number of deleted routes; therefore, establishing routes passing through nodes that have more routes stored in their memories will decrease the routing process overhead since the number of deleted routes will be minimized and there will be no need to search for a new route every time.

5.3 Packet delivery ratio

Packet delivery ratio could be defined as the number of packets successfully sent during a specified period of time relative to all sending attempts. Results are very close between the original DSR and our proposed ASDSR, this indicates that we can achieve the same throughput while decreasing network overhead and getting more stable routes using our proposed enhancement. These results are shown in Fig.7 below. The closest value was achieved by OF; outgoing links factor, where the number of neighbors for a node give it higher priority to be selected.

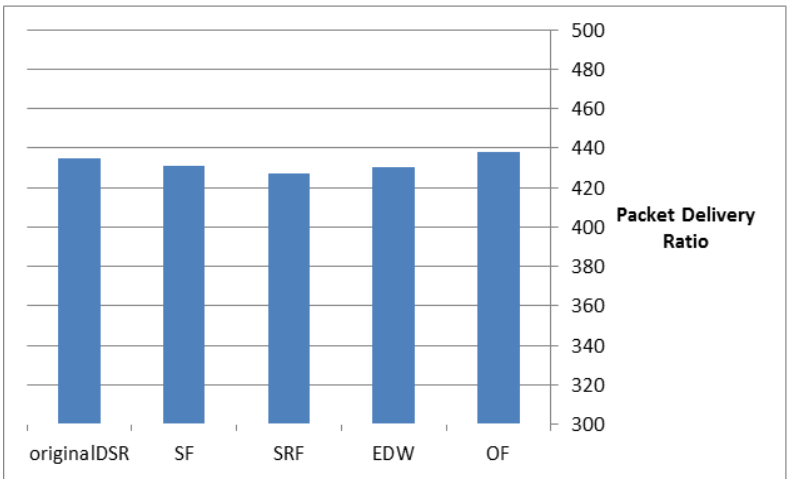

Fig. 7. Packet Delivery Ratio Metric

6 Conclusion

In this paper, we proposed ASDSR protocol as an enhancement on the DSR protocol, where the most stable route is found by restricting flooding Route Request Message (RREQ) to a subset of each node's neighbors according to a computed stability value based on three weighted factors; node speed, out-going degree, and the number of stored routes in nodes' cache memory. A dynamic and adaptive process was applied for selecting the percent of the neighbor nodes based on monitoring the packet delivery ratio and adjust the percent of neighbors included in the RREQ flooding process in a way that achieve an accepted packet delivery ratio. Our proposed ASDSR was evaluated using simulation; results were collected and compared with the original DSR protocol showed an enhancement in the overall routes stability about (0.13), and a decrease in the number of deleted routes by (9%), while maintaining an accepted value for the packet delivery ratio (0.86).

In the next study, we will make an exploratory study about network features that affect the selection process of weight values for each of the three factors and what are the suggested values for these weights at various scenarios.

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Fostering Student's Critical Thinking through a Virtual Reality Laboratory

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Abstract—Virtual reality (VR) laboratory is great potential for education. It is recognized as a technological advance that can facilitate a learning process through the development of highly realistic 3D visualization. Using VR laboratory in teaching and learning makes it possible to manipulate objects in the virtual scene in a manner similar to the real world. Virtual reality laboratory was developed to enhance the students' critical thinking skills. A Research and Development (R & D) method with a post-test design was used in the research. The subjects included the students who were enrolled at Senior High School in Yogyakarta, Indonesia with a total of 96 grade 10th students. The samples divided into three classes, namely EC-1 with virtual reality laboratory, EC-2 with virtual reality and real laboratory, and CC with real laboratory while the quality VR was applied to chemistry teachers. The findings of this research reveal that the quality of VR laboratory integrated hybrid learning was in a very good category. The results of students' critical thinking skills were analyzed using ANOVA test and it was found that there is a significant difference on students' critical thinking skills of the three classes. Students who took part in learning using VR laboratory both in the EC-1 and EC-2 classes had better critical thinking skills compared to the CC class. Thus, the VR laboratory is potentially used for further teaching-learning process.

Keywords—Virtual reality, 3D visualization, hybrid learning, critical thinking skills, laboratory.

1 Introduction

Computer programming is crucial in today's era and we are living in the place where computer programs are found everywhere [1]; [2]. Technological advances that are developing very rapidly make people rely on smartphone apps to manage their daily routines which fuelled by computer programming. Currently, virtual reality (VR) with 3D visualization has great potential for education. VR technologies have been applied in science and chemistry [3]; [4]. VR technology can improve students' academic performance [4]. It allows immersing a user in a 3D, interactive, provide students with visual, experiential, and self-directed learning [5]; [6]. Using in teaching and learning makes it possible to conjure visualisations that cannot be achieved using

a traditional method. The simulations of virtual reality were developed and appropriately placed in the teaching materials to enhance the student understanding of complex concepts and learn [7]; [8].

Simulations in virtual reality are interactive digital teaching and learning that imitate a real life. Simulations using virtual reality are also helpful because students can practice their skills that otherwise could be dangerous to practice in real condition [4]. Students who played simulations in virtual reality and then engaged in discussions that drew analogies between the simulations and concepts they were taught would learn more than students who did not play the simulations. The immersive VR may not be an optimal medium for learning basic concepts and facts, but could have greater potential in helping students develop their imagination through 3D interactions once the students have a basic understanding of the material [9]. In virtual worlds, students can be simultaneously provided with 3D visualization and learn to operate the virtual worlds via virtual reality laboratories. So, they can practice meaningful experiments and collect data.

The development of ICT has introduced a blender and a unity program that has not been used optimally as chemistry learning media. The program can be used to develop virtual reality with 3D visualization that can be operated with Android. The development of virtual reality is very promising for future technology that can be developed as a medium for virtual experiments. Using instructional media can make learning more interesting and motivating, more interactive, easier to understand subject matter, learning methods become more varied, learners become more active, and learning processes can take place anytime and anywhere [10]; [11]; [12]. Using 3D visualization in this research is also expected to be an alternative solution for schools that do not have laboratory facilities, both in the form of chemicals and other practical equipment.

The 3D visualization allows people to see things that cannot be seen in the real world and observe things from the real world in ways impossible in the real world [13]; [14]; [15]. By providing spatial information in visualization, it can make big steps to unite visual effects and information acquisition. A chemist needs visualization for the progress of the knowledge, especially in relation to complex chemical molecules. In chemistry, 3D visualization is very important for understanding spatial relations between atoms [16].

The popularity of the information technology has grown rapidly, especially e-learning. One of the developments of e-learning is hybrid learning that can present online course material in interactive and stimulating ways for students and creating an online learning community. Hybrid learning can use the Learning Management Systems (LMS) for example edmodo that allowing them to manage the distribution of assignments, quiz, and course material. The importance of e-learning has been highlighted previously and as a result online forum can be used as a place for interactive discussions [17]; [18]; [19]. Hybrid learning is being combined with independent online study and traditional classroom method [20]. Hybrid learning allow students to communicate with their peers and teachers thus empowering them to learn and discuss together online.

Online learning is one of the important communication and there are some systems that can be used such as e-mail, discussion boards, instant messages, and online forums [19]; [21]. Hybrid learning consists of synchronous and asynchronous technologies. Synchronous technologies can bring a real-time element into communicating online and enhance a learning experience [22]; [7]. Asynchronous technology is a good collaboration involving an interaction between teachers and students, although students cannot receive instant feedback [23].

Through the use of virtual reality (VR) with hybrid learning, students can be more visually aware of their classmates and converse in real-time with them [21]. They would receive feedback from teachers and allow them to actively involved in group discussions at the same time. VR is developed with 3D visualization with features of different shapes, objects, and animation. It makes learning more fun and can be used to teach students with different procedures for carrying out assignment [24]. Hybrid learning also brings a great deal to an e-learning experience, communicating online, and on providing adequate support for a variety of learning assignments.

The 21st century skills suggest a temporary core skill known as 4C which include critical thinking and problem solving, communication, collaboration, creativity and innovation [25]. Critical thinking skills are one of the skills that need to be developed in the current era. These skills include the skills of analyzing, evaluating, and synthesizing. Critical thinking skills can be defined as a person's ability to test their idea in dealing with problems the art of analysis and evaluating thinking, deducting and inferring conclusions from problems and facts [26]; [27]. In this research, we developed a virtual reality laboratory designed to train students' critical thinking skills so that they are accustomed to thinking deeply in solving problems encountered.

The main issues from the literature show that virtual reality can enhance students' critical thinking skills. We developed a virtual reality laboratory integrated hybrid learning to achieve research goals of improving students' critical thinking skills through the VR. Thus, the following research questions for this research:

1. How are the characteristics of virtual reality laboratory on chemistry?
2. How is the quality of virtual reality laboratory on chemistry?
3. Are there differences in critical thinking skills among students who use virtual reality laboratory integrated hybrid learning both as supplements and subtitutes with students who carry out practical learning in a real laboratory?

2 Method

This research used Research and Development (R&D) method - ADDIE model, including: analysis, design, develop, implement, and evaluate [28]. The development product was a virtual reality laboratory in a chemical bonding practicum course. The assessment of the effects of a virtual reality laboratory was conducted based on a post-test design where there were two experimental classes (EC-1 & EC-2) and one control class (CC). A total of 96 participants were recruited from three classes of 10th grade students of a senior high school. One class with a total of 32 students were cluster randomly selected as the experiment class-1; the second class with a total of 32 stu-

dents were assigned as the experiment class-2; while the third class with a total of 32 students were assigned as the control class.

The independent variable in this research was instructional media. The EC-1 used a virtual reality laboratory integrated hybrid learning, EC-2 used real laboratory and virtual reality laboratory integrated hybrid learning, while CC used real laboratory. The dependent variable was critical thinking skills and the posttest was obtained for measures. Chemical bonding tests were conducted to obtain data on students' critical thinking skills. It consists of 6 items of short essay questions. The posttest included the critical thinking skills. These measures had Cronbach's alpha reliabilities of 0.82.

2.1 Research design

The procedure of the research in this development refers to the ADDIE development model which can be explained as follows. The first step was initial needs analysis which included collecting information by observing learning activities directly in school and also through interviews with senior high school teachers. The purpose of this stage is to obtain various information regarding the availability of infrastructure, learning media, implementing learning, reviewing the curriculum to form indicators of achievement of competencies, and potential that can be developed from learning in schools. Besides, a literature study was also conducted by reviewing various existing literature such as journals, research reports, and other sources. The initial needs analysis is done by formulating a general description of the 3D visualization learning media that will be developed to suit the characteristics of the students. Based on the results of the analysis, a new approach is being developed in the making of 3D visualization objects by utilizing technological developments, such as augmented reality and virtual reality [29]; [30]. In Indonesia, the use of 3D visualization media based on virtual reality is still rare.

The second step was product design carried out by collecting various references as supporting components in the making of a virtual reality laboratory in the form of materials, animations, videos, images, color compositions, tools and materials as well as procedures for experimental simulation. Practicum designed in this VR was chemical bonding course. The third step was a development of VR products. Virtual reality laboratory products were developed using a blender and unity on computer programs. The blender program serves to build 3D visualization objects, animations in simulations, and compose textures from 3D object components. After all 3D objects are created, then combine all the objects and make the object interaction using the unity program. After all 3D visualization objects are filled into one unit on a computer, virtual reality laboratory product can be used using smartphones (Android).

The next step was an implementation by testing virtual reality laboratory products. Tests were conducted with the experimental class (EC-1 and EC-2) and the control class (CC) to test the effectiveness of the product developed through the students' critical thinking skills. The last step was product evaluation by evaluating VR product quality to senior high school teachers. The product implementation phase uses the quasi-experimental method with posttest design which can be seen in Table 1.

Table 1. Posttest design

Classes	***Treatment***	***Post-test***
Control Class (CC)	X1	P1
Experiment Class -1 (EC-1)	X2	P1
Experiment Class -2 (EC-2)	X3	P1

Note: X1 = learning with real laboratory, X2 = hybrid learning mediated by virtual reality, X3 = learning with real laboratory and hybrid learning mediated by virtual reality P1 = chemical bonding test

2.2 Data analysis

Analysis of Variance (ANOVA) technique and qualitative descriptive were used to analyze students' critical thinking skills. Quality of virtual reality laboratory was analyzed by quantitative descriptive method. Thus, the data were classified into a category based on the ideal rating category. The rating category can be seen in Table 2.

Table 2. Ideal rating category

Score	**Range Quality**
$\underline{X} > \underline{X_i}$ + 1.8 SBi	Very Good
$\underline{X_i}$ + 0.6 SBi < $\underline{X} \leq \underline{X_i}$ + 1.8 SBi	Good
$\underline{X_i}$ - 0.6 SBi < $\underline{X} \leq \underline{X_i}$ + 0.6 SBi	Good Enough
$\underline{X_i}$ - 1.8 SBi < $\underline{X} \leq \underline{X_i}$ - 0.6 SBi	Poor
$\underline{X} \leq \underline{X_i}$ - 1.8 SBi	Very Poor

Note: X is the empirical score; X_i is the average of ideal scores; SBi is the ideal score of standard deviation

3 Results

3.1 Developing process

The ability of providing highly interactive learning experiences was one of the best-valued features of virtual reality. We decided to use Blender and Unity on computer programs which have good support to build 3D objects. Blender is a program for modeling, animation and rigging and Unity is for implementation [31]. Blender was chosen as the primary tool for all 3D modeling and animation. It can be used for modeling 3D objects, rendering, rigging, UV mapping, sculpting, animation, etc. The 3D objects created in this program include: laboratory room, cupboard, tables, clamp, burets, beakers, magnets, funnels, and other laboratory equipment. The 3D objects that have been created are then rendered so that the object's appearance becomes clear and appropriate. The 3D model being built in Blender can be seen in Figure 1.

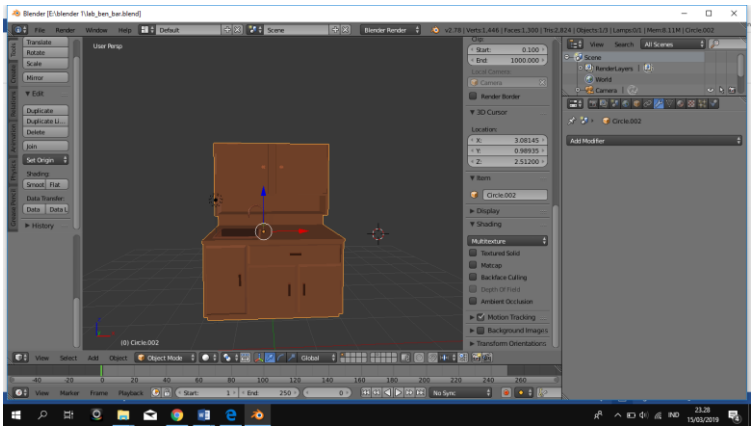

Fig. 1. The 3D Model being built in Blender

Furthermore, all 3D objects integrated into Unity programs. Unity is best suited for small or middle-sized development studios and combines visual simulation capabilities with interactive functions and ease of use in the context of geometry data input and output [31]; [32]. The 3D objects which has been incorporated into the Unity program can be seen in Figure 2.

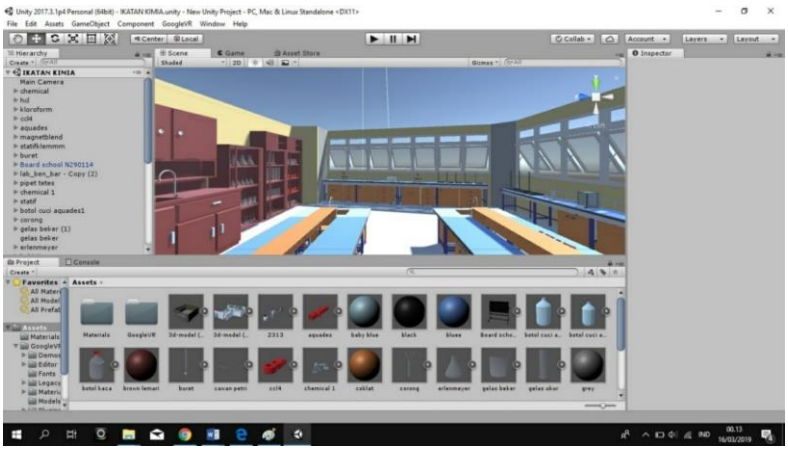

Fig. 2. Virtual reality laboratory in Unity

This virtual reality laboratory can only be operated using Android. However, we can monitor via computer using the "Team Viewer" program. VR displays on computers can be seen in Figure 3.

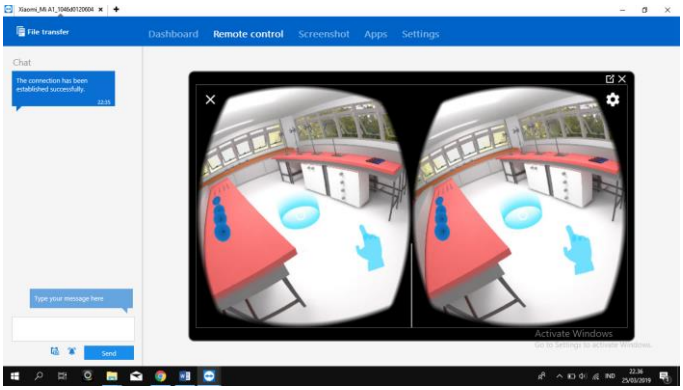

Fig. 3. VR display on a computer through the "Team Viewer" program

Virtual reality can be operated using an Android equipped with 3D glasses and a controller. The simulation allows students to virtually work through polarity compounds in a lab. It starts by introducing the students to the virtual laboratory environment. The VR simulation increases motivation by having students experience the excitement of learning, increases critical thinking and conceptual understanding, increases scientific skills by having students test, explore, predict, observe, and makes sense of relevant material in a virtual environment that simulates real laboratory [33]; [34]; [35].

3.2 Effect of virtual reality on critical thinking skills

The implementation of VR laboratory products aims to measure students' critical thinking skills. The results of product implementation are the post-test values of critical thinking skills which can be seen in Table 3 and the summary of ANOVA can be seen in Table 4.

Table 3. Descriptive statistics of critical thinking skill

Classes	N	Mean	SD
Control Class (CC)	32	67.5	12.8
Experiment Class -1 (EC-1)	32	79.4	11.8
Experiment Class -2 (EC-2)	32	77.5	9.8

Table 4. Summary of ANOVA analysis

F Value	Sig. Value	Conclusion
9.789	0.000	Significantly different

The highest average of critical thinking skills was obtained by experimental class-1 and followed by experimental class-2. Both classes applied learning using an integrated hybrid learning virtual reality laboratory both as a supplement and as a substitute. The combination of virtual laboratories has a positive effect on students' learning

outcomes in conducting experiments [36]. This is also in accordance with the statement of Higgins et al. (2012) the use of technology in the interaction between educators and students has a good impact on student learning outcomes because learning is more effective.

Based on Table 4, it shows that there is significant influence of virtual reality integrated hybrid learning towards students' critical thinking skills. Practicum using virtual reality makes students more active and enthusiastic in participating in learning, unlike the practices in a real laboratory that makes students saturated and less active because they cannot develop their imagination [36]; [37]. Based on observations during the learning process, class EC-1 and EC-2 obtained better results because students in both classes had high curiosity, always asked questions in learning, and were active in discussion and presentation activities. This is also supported by the application of hybrid learning in EC-1 and EC-2. The lessons with VR laboratory allow more effective learning experience with significant improvements compared to learning with traditional lessons alone [38].

Implementation of integrated virtual reality hybrid learning laboratory was conducted in 4 meetings. Hybrid learning is carried out with face-to-face and online phases: synchronous and asyncronous. The online phase in the learning process uses various programs in the computer, including skype, instant messaging (IM), e-mail, and online discussion forums. The online phase in hybrid learning provides additional learning time to students, can add a reference to learning resources, influences learning outcomes, and encourages an interaction among students [39]; [40]. Hybrid learning makes students capable of working together in groups and solving problems together well. With the data obtained through discussion and practicum activities they would try to combine the data they obtained both from practicum and discussion with data obtained from other sources during hybrid learning. Thus, they will be trained to think critically in solving problems.

The quality of VR applied to 8 senior high school teachers consists three aspects, namely content, learning and technical quality. These three aspects were described into 22 indicators. The quality of VR for each aspect can be seen in Table 5.

Table 5. The quality of VR

Aspects	**Average Score**		**Category**
	Total	***Maximum***	
Content	30.20	32	Very good
Learning	29.44	32	Very good
Technical	30.13	32	Very good

Based on Table 5, the quality of VR laboratory integrated hybrid learning is in a very good category. Teachers considered that the VR was assumed to be easy to understand, motivated students to help their learning process, and the display of VR was clear like real laboratory. Teachers stated that the presence of a virtual reality laboratory would make students more enthusiastic in attending classes. This is supported by the development of the digital era where students are more flexible in practicing virtually with clear 3D objects and interaction in media that is fun and easy to operate.

The virtual chemistry laboratory has been successfully developed as experimental media, improvement of students' creativity, has instructional characteristics with a positive contribution to education, improves students' achievement and the quality of the virtual chemistry laboratory integrating hybrid learning is in a good category [41]; [42]; [43].

4 Limitations and Suggestions for Future Work

Although the study provides positive results, there are still some limitations in this study. First, this virtual reality laboratory product can only be operated using Android. Second, practicum material in this media only contains one subject, so it is necessary to develop VR laboratory media on another subject. Thirdly, this media does not yet have audio due to limitations on 3D glasses that are not yet equipped with headphones.

Suggestions for the use of virtual reality laboratory products based on the results of research and development that has been done is that the virtual reality laboratory media can be further developed with different material and can be used as action research. Furthermore, further research is needed to measure the effectiveness of the use of 3D visualization media in virtual reality on a broader scale. In addition, it is necessary to develop more virtual reality laboratory media with the addition of more complex, interactive 3D objects. It is necessary to add audio and learning games in this media.

5 Conclusion

Based on the results of research and development of integrated hybrid virtual reality laboratories, the conclusions are that the characteristic of virtual reality laboratory is that this media can be operated using android with the help of 3D glasses and a controller. This simulation in 3D visualization is a compound polarity practicum on chemical bond material in a virtual environment so it is as if the user is doing a practicum in the real world. The quality of virtual reality laboratories in chemical bonding material is a very good quality in terms of learning, content, and techniques based on the assessment from the chemistry teachers. There are significant differences in critical thinking skills between students who use virtual reality laboratory integrated hybrid learning both as supplements and substitutes with students who carry out practicum learning in a real laboratory.

6 Conflict of Interests

The authors declare there no conflict of interest.

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A Novel Greedy Forwarding Mechanism Based on Density, Speed and Direction Parameters for Vanets

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Abstract—In the recent years, the study and developments of networks that do not depend on any pre-existing infrastructure have been very popular. Vehicular Ad Hoc Networks (VANETs) belong to the class of these networks, in which each vehicle participates in routing by transmitting data for other nodes (vehicles). Due to the characteristics of VANET (e.g. high dynamic topology, different communication environment, frequently link breakage), the routing process still one of the most challenging aspects. Hence, many routing protocols have been suggested to overcome these challenges. Moreover, routing protocols based on the position of vehicles are the most popular and preferred class, thanks to its many advantages like the less control overhead and the scalability. However, this class suffer from some problems such as frequent link breakages caused by the high-mobility of vehicles, which cause a low PDR and throughput. In this investigation, we introduce a novel greedy forwarding strategy used to create a new routing protocol based on the position of vehicles, to reduce the link breakages and get a stable route that improves the PDR and throughput. The proposed Density and Velocity (Speed, Direction) Aware Greedy Perimeter Stateless Routing protocol (DVA-GPSR) is based on the suggested greedy forwarding technique that utilizes the density, the speed and the direction of vehicles for selecting the most convenient relaying node candidate. The results of simulation prove that DVA-GPSR protocol outperforms the classical GPSR in all studied metrics like PDR, throughput, and the ratio of routing overhead by changing the quantity of vehicles in urban and highway scenarios.

Keywords—VANETs, Routing protocol, GPSR, DVA-GPSR, direction, speed, density.

1 Introduction

Vehicular ad-hoc networks or VANETs in short, are a kind of a self-structured network that are designed directly by a set of intelligent vehicles. Each vehicle is equipped with a wireless transceiver and considered as a router. Some VANETs' features such as high link breakage, high dynamic topology and the high speed of vehicles make the task of routing data packets in the networks a very big challenge for researchers. Therefore, many researchers focus on designing the routing protocols, which are suitable for all vehicular scenarios and deal with those characteristics.

Routing protocols in VAENTs could be categorized into four classes [1], but those that are based on the position of vehicles are the number one thanks to their scalability and less control overhead [2]. In this paper, a novel routing protocol based on the location of vehicles is proposed that is based on four parameters; the density, the speed, the direction and the distance between destination and the relaying candidate node. These parameters are combined and used to improve the classical greedy forwarding strategy of GPSR routing protocol, this combination will create a new routing protocol called Density-Velocity-Aware- GPSR (DVA-GPSR) that will affect and enhance the performance of VANETs in urban and highway scenarios. As mentioned above, DVA-GPSR protocol selects the best relaying node by considering three parameters other than the classical one of GPSR. The first parameter helps us to calculate the angle between the direction of the relaying candidate and the direction of the target vehicle, this parameter is the angle direction. In order to increase the link lifetime between two vehicles, the second parameter that is the speed variation between the target node and the relaying candidate vehicle will be used to look for the smallest variation. The density or the neighbors' number of the relaying candidate vehicle is the third parameter, which helps to determine the connectivity mode in each path (sparse, medium or dense). These parameters are used to improve the PDR, the throughput and the routing overhead in the network for the classical GPSR in the proposed scenarios.

We have split this paper into six sections and each one describes a part of the paper profoundly. The paper is organized as follows. The related works are presented in section II. The original GPSR routing protocol, its benefits and drawbacks are provided in detail in section III; after that in section IV, we present and explain the strategy of the proposed DVA-GPSR. Section V presents the performance evaluation of the proposed DVA-GPSR based on simulation tools, and then the result analysis will be compared with the original GPSR. In section VI, we conclude this paper and present some of our future works.

2 Related Works

In this section, we are going to give an overview of some enhancements applied to the classical GPSR for VANETs. We will present mainly the most recent and cited papers.

In [3], Bouras et al. proposed a modified GPSR routing that is based on three parameters direction information, the speed of vehicles and the link quality in addition to the location information to select the next hop. Mainly, by using those parameters the future positions of only the source and the destination vehicles could be predicted. The benefits of GPSR-Modif is that it has a high value of PDR compared to the traditional GPSR, while keeping the E2ED (end-to-end delay) at the same level as GPSR. In [4] Silva et al. propose an adaptive GPSR (AGPSR) to enhance both the GF strategy and the PM technique of the classical GPSR. The GF technique is improved by using a special parameter called trust status TS. Moreover, AGPSR improved the PM technique by replacing it with a continuous greedy strategy. The proposed protocol proves high performance, but only for static nodes. In [5], Tu et al. provided a new

modified GPSR based on Moving Vector, (GPSR-MV) to enhance both the GF and the PM techniques, by taking the vehicles' fast moving and forwarding efficiency into consideration and combining it with a simplified perimeter forwarding to avoid loop problem. The results show that GPSR-MV has a significant enhancement compared to the classical GPSR. GPSR-2P[6] Zaimi et al. developed GPSR-2P protocol, to resolve the congestion and saturation problems. Actually, authors replace the GF technique by introducing the multipath strategy only if the same node transmits two successive packets to the same destination; otherwise, the simple GF will be applied. The proposed enhancement of GPSR has significant results in case of PDR end E2ED. GPSR-2P is not efficient in case of more than two packets. In another paper, Yang et al. proposed

All the above papers do not clearly adopting the enhancement of GPSR protocol to be implemented in a highway environment or in real map scenario. Moreover, the proposed enhancements used very complex techniques and weighted functions to select the next hop node. This paper is farther enhancing the GPSR approach by adopting both the highway and the urban environments by using a real map scenario. Moreover, the proposed technique is based on a simple and novel mechanism to select a next-hop node in VANETs.

3 The Strategy of the Traditional Gpsr Protocol

GPSR [7] is the most popular position-based routing protocol that relies on geographic location information. In GPSR, two methods are utilized to transfer packets. The greedy forwarding (GF) in which the source select the closest neighbor to the target node as next hop to relay packet this method will be replaced by the perimeter forwarding (PF) in case of the failure as shown in Figure 1. The strong point of GPSR is that each vehicle could have the exact neighbor's information as the geographic location, the speed and the direction movement. However, in the classical GPSR only the location information is used in the selection of the next hop process that could be inaccurate. Furthermore, the use of the greedy forwarding technique reduces the number of hop from source to destination. However, the transmission quality of the connection link is totally ignored. This strategy causes a significant amount of packet drops that decreases the PDR and throughput. Moreover, for each link failure a new route has to be reestablished so the forwarded data will be suspended until a new relay node is found. As a result, the routing overhead is dramatically increased.

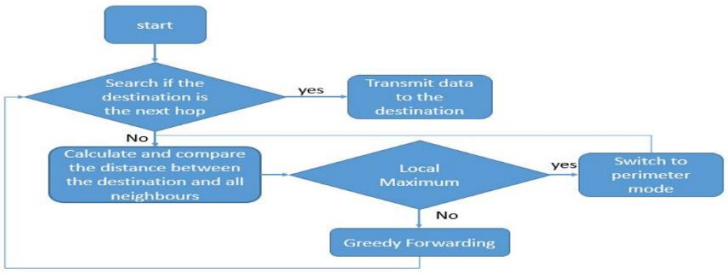

Fig. 1. The mechanism of selecting the next hop for GPSR

4 The Strategy of the Proposed DVA-GPSR

Our proposed scheme is built on top of the traditional GPSR protocol. It adopts that all vehicles in VANET have a GPS able to giving the accurate vehicle's information and they are equipped with an On-Board Unit (OBU) wireless transceiver/receiver for connecting each other. Hence, our main involvement is that we suggest a Novel greedy forwarding mechanism. In fact, a simple weighted function is used to select the most convenient relaying vehicle; the function consists of the angle direction, the speed variation and the density of the relaying candidate node, in addition to the classical parameter of GPSR that is the distance between the relaying candidate vehicle and the target vehicle. Then an improved GPSR protocol called DVA-GPSR is provided based on our proposed strategy.

4.1 The novel greedy forwarding mechanism

As mentioned previously, the Source vehicle starts gather the mobility parameters: velocity and the position of all its neighbors. These parameters are implicated in the proposed function to calculate the link weight of all its neighbors.

- At first, we calculate the angle direction φ (Figure 3) between each next hop candidates and the destination node as according to formula (1).

$$\varphi_{id} = \cos^{-1} \frac{\left((iVelocity.x * dVelocity.x) + (iVelocity.y * dVelocity.y)\right)}{\left(\sqrt{(iVelocity.x^2 + dVelocity.x^2)} * \sqrt{(iVelocity.y^2 + dVelocity.y^2)}\right)} \quad (1)$$

Where iVelocity is the velocity of the next hop candidate and dVelocity is the destination velocity. The rational between the concepts of the angle direction is to maintain the connection between vehicles as long as possible by choosing the small value of all calculated φ_{id}.

- Secondly, the distance between the sender and the destination node is calculated according to formula (2).

$$D_{id} = \sqrt{(y_i - y_d)^2 + (x_i - x_d)^2} \quad (2)$$

Where (x_i, y_i) signifies the location of the neighbor node called i and (x_d, y_d) denotes the destination location.

- The third parameter is used to calculate the speed variation between the target node and the next hop candidate node.

$$S_{id} = |S_i - S_d| \quad (3)$$

Where S_i is the speed of the neighbor node called i and S_d denotes the speed of the destination node.

The previously mentioned equations will be used to formulate the weighted function (4). The link weight is calculated for every neighbor of the source node. If one of the

neighbors vehicles have almost the same speed and direction as the destination as well as the calculated distance is reducing and the density of the neighbor is high or medium then the link connection is more stable. Hence, we will select vehicle that has the lowest weight value as the next-hop relay node. The formula (4) presents the weighted function of the next-hop candidate node called i.

$$LWF = \alpha * D_{id} + \beta * \left(\frac{1}{density_i}\right) + \theta * S_{id} + \gamma * \varphi_{id} \quad (4)$$

Where the $density_i$ is the number of neighbors for the next hop candidate i, used to determine the connectivity mode in each path (sparse, medium or dense) thus reduce the sparse connectivity problem; and $\alpha + \beta + \theta + \gamma = 1$, to choose the most accurate values of those factors several simulation had done.

The problem of void area that often arises by using the classical GPSR, which lead to the local maximum issue, will be resolved by taking into account the density parameter in the novel greedy forwarding strategy to select the most suitable next hop. Indeed, the vehicle that has the high density (high number of neighbors) will be chosen as a relaying node; hence, the problem of local maximum is reduced. Moreover, the Figure 3 clearly explains the strategy, the source vehicle will choose A as a relaying vehicle since it has three neighbors while B has no neighbors.

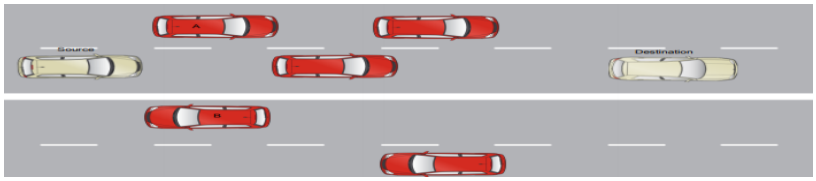

Fig. 2. The density of node A and B

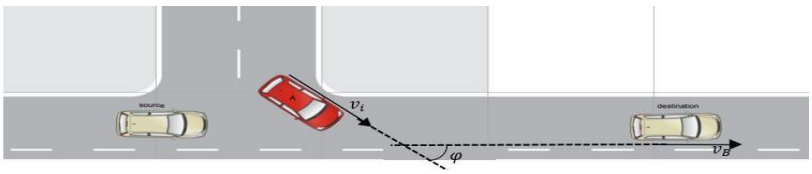

Fig. 3. The angle direction φ

4.2 The algorithm of DVA-GPSR

The algorithm of Density-Velocity-Aware based on GPSR (DVA-GPSR) is as follow:

```
Algorithm 1. The partial DVA-GPSR Strategy
Read the neighbor table of node S;
For i=1 to the end of neighbor table
    Wi = Calculate_weight(i);
     If Wi < Wi-1
           Set node i as the best next hop;
     End if
End for
If i.addr->isValid()
  Transmit data to node i;
Else recoveryMode();
End if
End algorithm
```

In this algorithm, S represented the source node and i presented the neighbor nodes. The source node gets all necessary information then calculates the proposed link weight formula between it and all its neighbors and put it in W_i. From the previous explanations, the neighbor that has the smallest value of W_i will be chosen as the next hop, otherwise the classical recovery process will be applied.

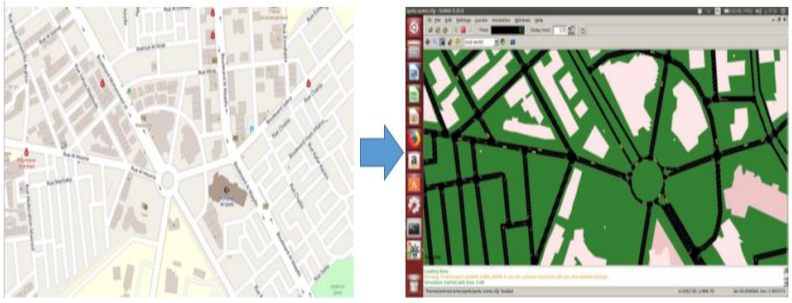

Fig. 4. Hay Alquds Oujda map from OSM to SUMO

5 Simulation and Comparison

In this section, we evaluate the performance of the proposed DVA-GPSR in terms of routing overhead, packets delivery ratio (PDR) and average throughput with different vehicles' densities and number of destinations. The simulations are performed under NS3 and SUMO as network simulator and traffic simulator respectively. For urban simulations, we extracted the map of a part of Oujda city with 1.7 km * 1.5 km from OpenStreetMap

For highway simulations, we are based on a highway scenario of 300 m * 1.5 km with four lanes in two opposite directions. The other different settings of simulation scenario are presented in Tableau 1. For DVA-GPSR, to find the most efficient values of α, β, γ

and θ of the proposed function, we done several simulations with different values. The different results are generated and drawn by using Gnuplot software.

Table 1. Tableau 1 Simulation parameters

Parameters	Measures
Number of nodes	20,30, 40, 50, 60, 70, 80, 90
Source/destination selection	Random
Destination number	10
Vehicles speed	Max: 20 m/s
Simulation time	200 s
Transport protocol	UDP

5.1 Impact of the number of vehicles in the network

Packet Delivery Ratio (PDR): Figure 5-a shows the results in a highway scenario, in terms of PDR by varying the number of vehicles. The PDR for DVA-GPSR protocol increases when the number of vehicles increases up to 68% while the PDR for GPSR decreases down to 59%. Figure 5 -b presents the same comparison for an urban scenario. We note that for DVA-GPSR protocol, PDR stays stable between 30% and 31% when the number of vehicles increase while the PDR of GPSR decreases down to 24%.

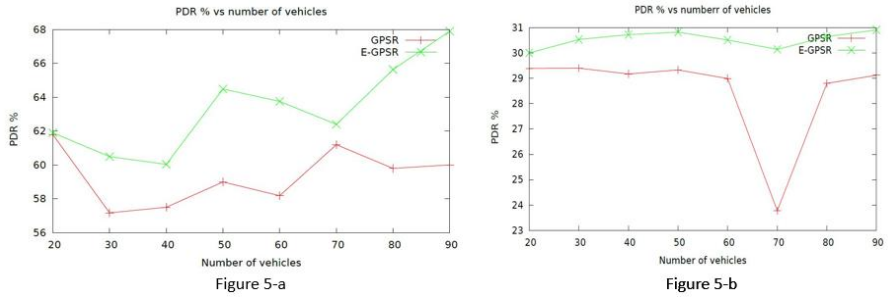

Fig. 5. Effect Change on density Respect to PDR in urban and highway scenarios

Average throughput: Figure 6 - a shows the results for both protocols in a highway scenario, in terms of the average throughput by varying the number of vehicles. The average throughput for both protocols increases when the number of vehicles increases. However, for DVA-GPSR protocol the throughput is increased up to 14 kbps while for GPSR it does not exceed 13 Kbps. Figure 6-b presents the same comparison for an urban scenario. We notes that for DVA-GPSR protocol, the throughput stays stable between 6 kbps and 6.5 kbps when the number of vehicles increases while for GPSR the throughput decreases down to 4.8kbps.

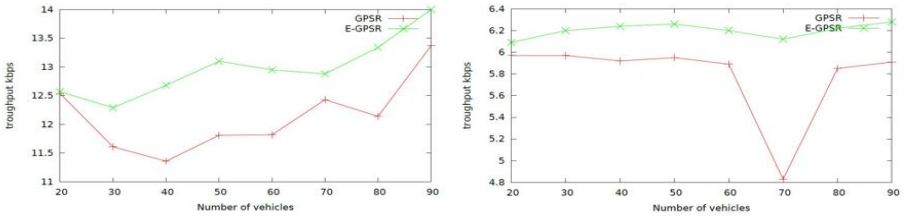

Figure 6-a Figure 6-b

Fig. 6. Effect Change on density Respect to throughput in urban and highway scenarios

Routing control overhead: Figure 7 shows that the DVA-GPSR performs better than GPSR during the simulation in both scenarios. Figure 7-a presents the results for a highway scenario, by varying the number of vehicles when we have 10 randomly selected destinations. We note that for both protocols the overhead decreases when the number of vehicles increases but DVA-GPSR has the low values of overhead down to 27.6% compared to GPSR. Figure 7-b presents the same comparison for an urban scenario in terms of routing overhead. The overhead for DVA-GPSR is low than the overhead for the classical GPSR and does not exceed 28.5%.

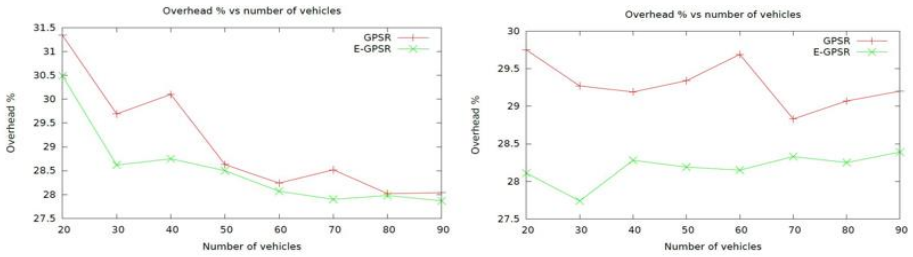

Figure 7-a Figure 7-b

Fig. 7. Effect Change on density Respect to overhead in urban and highway scenarios

6 Conclusion

In this paper, we have proposed a novel greedy forwarding mechanism based on Density, Speed and Direction parameters for VANETs then we applied the proposed strategy on the classical GPSR routing protocol to be more convenient for VANETs scenarios. To prove the high performance of DVA-GPSR, we are based on a real urban environment, which is a part of Oujda (Al-Quds street). Simulation results demonstrate that the proposed DVA-GPSR outperforms the classical GPSR routing protocol in terms of better control packet overhead, PDR, and average throughput. For future works, we aim to take into account more impacting parameters to the routing protocol to support urban environment structures, and other performance metrics that related to QoS can be simulated and tested with different traffic scenarios.

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