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"E-LabSheet Project" 4Cs-Based Supplementary Media for Flexible Learning: Is it Well Implemented?

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Abstract—This research aims to design and develop a learning product named the "E-LabSheet Project." E-LabSheet is a supplement to the computer network practicum. This module contains the 4C's of 21st-century skills to practice critical thinking, problem-solving, creativity, communication, and collaboration, organized in materials, exercises, assignments and integrated with the video tutorials. Furthermore, this E-LabSheet is very simple to use because it can be read with a mobile device, which has become the daily life of 21st-century students known as Gen Z. In this study, the validity, practicality, and effectiveness of the product were tested. The development model used is 4D. For the validity test, the validation sheet consists of media aspects and material aspects by experts. To find out the practicality, we used a questionnaire with a g-form which was then filled out by students as users. Atrial was conducted on two classes to determine the effectiveness of the media. The first class (class A) was treated without E-LabSheet media, and the second class (class B) was treated by giving a supplement in the form of E-LabSheet. The results of this study stated that the developed e-LabSheet media was successfully categorized as valid, practical, and effective. This module is a complementary media for flexible learning that can improve student learning outcomes for the better, especially in 4C skills. The comparison of the learning outcomes of the two classes showed that class B, which was given supplementary media, obtained better learning outcomes than class A.

Keywords—E-LabSheet, 4Cs, supplementary media, flexible learning

1 Introduction

A good learning media has several criteria, including having an attractive appearance and being easy to use, providing a learning experience for students, and improving learning outcomes [1]. The media developed must be prepared as well as possible, especially in preparing content or learning materials to improve learning outcomes. This must follow the learning objectives to be achieved [2], [3]. Currently, along with technological developments, we can develop technology-based learning media, such as e-learning, electronic books, AR/VR-based media, etc. [4], [5]. Electronic books have become a learning resource we often use [6]–[9]. The simplest electronic book is a book that can be read using a mobile device as a PDF file.

Two years ago, during the COVID-19 period, learning in schools, both elementary and high school levels, had fully implemented distance learning or fully online [10]. The use of technology in the teaching and learning process is a must. The COVID-19 pandemic is a catalyst that encourages increased use of technology in various sectors of life. In the field of education, almost all activities in universities have used technology, for example, such as webinars, e-learning, and virtual meetings via zoom and google meetings, especially in the informatics engineering education study program, where students are the primary users of technology and the internet in their daily lives [11], [12]. Then currently, teaching materials and learning resources are very varied, such as video-based media, problem-based media, case-based media, AR-based media, and even VR-based media. Learning resources are also currently very open and expansive because of the internet [4], [13], [14] for example, we can learn almost everything through Google or videos from YouTube [15].

Currently, specifically for the computer network practicum course at the Universitas Negeri Padang, the learning process has been supported by facilities in the form of laboratories and all the equipment. However, the practicum module used needs an update in content and technology. For example, the current practicum module is paper-based, although some are digital (e-book), only in a file format converted from an existing document (PDF). The current condition is uncertain; the learning process can be done in class, at home, or virtual. Blended learning has also been applied in both theory and practice courses. The challenge of the previous practicum learning process was that the students faced some difficulties in online learning, such as poor internet connection, lack of motivation, and quick get distracted. In addition, the existing electronic modules are less attractive and less varied, so students are lazy to read [13], [16], [17].

Based on the previous year's study results, student learning outcomes in the computer network practicum course are still low due to the lack of student motivation to read the practicum module, which impacts learning outcomes. The previous year's study results are evidenced by the learning outcomes data from 3 classes: X, Y, and Z, as shown in Table 1. Then the existing modules have not been able to train 4C skills, which are now the skills needed to face the challenges of the 21st century. It is also supported by questionnaire data from students taking this course; 74% of students stated that the existing media is less attractive because it is dominated by text-based content and static images. As many as 72% of students stated difficulties in practicum because the modules used were less attractive and there were no video tutorials, so each student looked for their respective video tutorials on the internet and causing a practicum workflow that was not in accordance with the standards or learning plans that should be. In line with research conducted by Wibawa & Sunarsih [18] impact learning outcomes. This is also supported by the research of Chang & Hwang [19] who developed a game-based electronic module that has proven that selecting the right media will positively impact student learning outcomes.

Table 1. Class X, Y, and Z learning outcomes in 2021

Class	Total Students	Details	Final Score	Grade	Range	Rate
X	15	8	75–100	A, A–, B+	High	53%
		3	55–74	B, B–, C+, C	Mid	20%
		4	0–54	C–, D, E	Low	27%
Y	15	6	75–100	A, A–, B+	High	40%
		7	55–74	B, B–, C+, C	Mid	47%
		2	0–54	C–, D, E	Low	13%
Z	15	9	75–100	A, A–, B+	High	60%
		4	55–74	B, B–, C+, C	Mid	27%
		2	0–54	C–, D, E	Low	13%

In Table 1, we look at last year's student learning outcomes. In this table, we divide the categories of student learning outcomes into 3 types: high, medium, and low. For the high category, the final score range is 75–100 with grades: A, A–, and B+. While the mid category, the final score range is 55–74 with grades: B, B–, C+, and C. Finally, the low category has a final score range of 0–54 with grades: C–, D, and E.

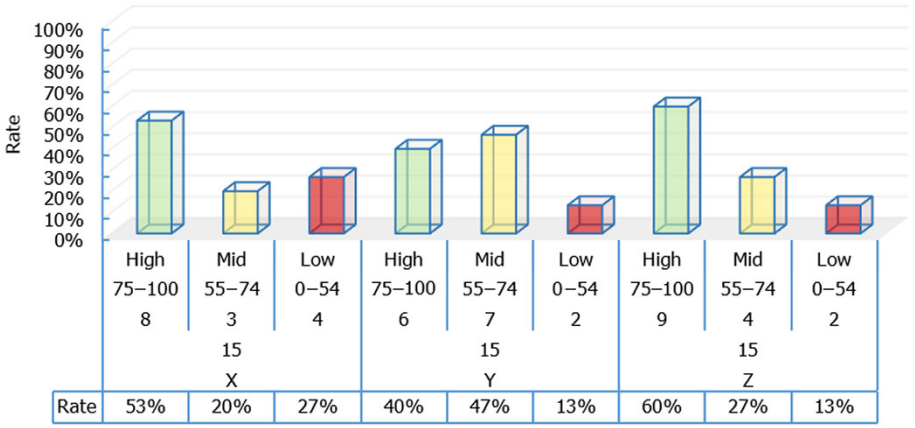

Fig. 1. Details of the distribution of students' final grade

In Figure 1, it is clear that there are students with low category scores (red bars), as many as 27% from class X, 13% from class Y, and class Z. So, to overcome the problems that occur, we take the initiative to develop the media that students need to support learning. Based on our observations and interviews with students who have taken this course, they stated that they prefer interesting and interactive media, which is then equipped with video tutorials. In addition, they also choose mobile or paperless-based media because they are easier to carry and can be read anytime and anywhere. Therefore, we chose to develop learning media that can later be used as complementary media, namely the ***"E-LabSheet Project"***. This E-LabSheet is prepared with a detailed

and easy-to-understand material explanation, then equipped with a practicum guide and integrated with learning videos so that it is possible to study independently. Then the composition of the material and practicum activities is compiled and packaged in its entirety; this E-LabSheet is also very easy to use and flexible with computers and mobile devices. The components that build E-LabSheet are also made as attractive as possible, with background sounds and interactive navigation. With this e-LabSheet, it is also hoped that students can learn according to their learning speed and style.

Finally, the developed E-LabSheet also embeds 21st-century skills, namely 1) *critical thinking and problem-solving*; 2) *creativity*; 3) *communication*; and 4) *collaboration* [20], [21]. These four 4Cs skills will train a person to be creative, divergent thinking ability that can provide different solutions from others about a problem; have sufficient knowledge and relevant experience; have the ability to communicate so that they can exchange information with their colleagues; can think critically and have good analytical skills. With this supplementary media, it is hoped that it can improve student learning outcomes for a better computer network practicum. In addition to providing hard skills through practice, it also provides 4Cs soft skills. The development of this practicum module uses a 4D development model, which consists of 4 steps that will be explained in more detail in the method.

2 Methods

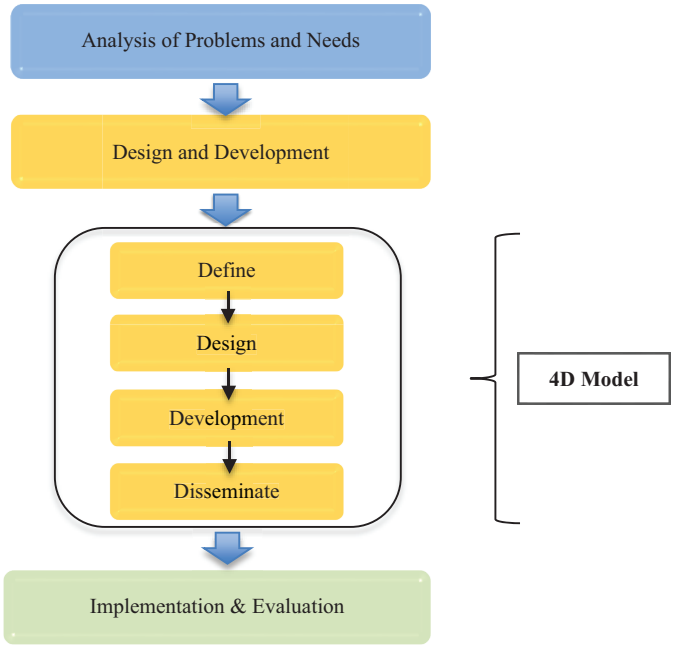

Fig. 2. Research and development procedures

This research is included in R&D research. This research and development procedure is divided into 3 main stages: 1) ***analysis of problems and needs***; 2) ***design and development***; 3) ***implementation and evaluation***. In the second stage, we use a 4D development model consisting of 4 stages: ***define***, ***design***, ***develop***, and ***disseminate*** [22] as seen in Figure 2. In the first stage, problem analysis is carried out to identify and determine the problems encountered in the learning process and then compile a list of needs needed in media development. This article explains the preliminary analysis, description of facts, and alternative problem-solving clearly in the introduction session.

The next stage is design and development. The 4D model starts to be implemented at this stage. First, perform an analysis of user needs. User analysis is an activity to identify the characteristics of students who are the target of developing learning tools. The characteristics in question are related to academic abilities, cognitive development, motivation, and individual skills related to learning topics, media, formats, and languages. Next is a concept analysis regarding the semester learning plan, which includes learning objectives, competencies, learning resources, practicum schedule, technology, and equipment.

Next is the 4D development process. First, the user interface design: colours, font size, layout, and background images, then proceed with compiling content, content, and navigation. This stage focuses on the product to be developed. The result of this stage is the initial product. The product will be tested for media validation by experts from both the media and material aspects. The validation test used an instrument in the form of a validation sheet filled out by 3 experts. Details of the aspects tested can be seen in (Table 2). A Likert Scale measured the test results of all aspects. A Likert scale is several positive or negative statements about an object or product. The basic principle of the Likert scale is to determine the position of a person on the continuum of attitudes toward an object of attitude ranging from very negative to very positive (Table 3).

Table 2. Media and material aspects

No.	Media Aspect	Material Aspect
1	Quality and Appearance	Content
2	Interactivity	Readability
3	Navigation	Material Presentation

Table 3. Likert scale classification

Scale	Classification
5	Excellent
4	Very Good
3	Neutral
2	Fair
1	Bad

The results from this expert assessment are calculated using the following formula (1), and then the percentage of results can be calculated using the following formula (2). In contrast, the classification of validation criteria can be seen in Table 4. In the classification of criteria, we divide it into 3 types: 81%–100% in the valid category, 61%–100% in the valid category, but revision is needed, and below 60% is declared invalid.

$$\bar{x} = \frac{\sum X}{n} \tag{1}$$

$$v = \frac{\sum x\ expert}{\sum x\ max} \times 100\% \tag{2}$$

Note:
$\bar{x}$: average score
ΣX: number of raters (expert)
n: total score of each
Σx *expert*: total exp score
Σx *max*: max score

Table 4. Validation criteria

No.	Percentage	Criteria
1	81–100%	Valid
2	61–80%	Valid & Need Revision
3	0–60%	Invalid

The dissemination stage can only occur if the tested product is declared valid. In testing the effectiveness, we involved two different classes: class A and class B. Class A was not given special treatment, while class B was given special treatment (with E-LabSheet media). The implementation results will be used as evaluation material for future improvements.

3 Results and discussion

3.1 E-LabSheet project

The following results from the design of the developed E-LabSheet media are shown in Figure 3 below. Figure 3 is a preview of the E-LabSheet cover design. The selection of blue, black, and white gradations illustrates the value and impression of "technology." E-LabSheet consists of material equipped with practicum videos that students can access via smartphone and the internet. For the media menu display, see Figure 4.

Fig. 3. E-LabSheet project: 4Cs-based supp. media

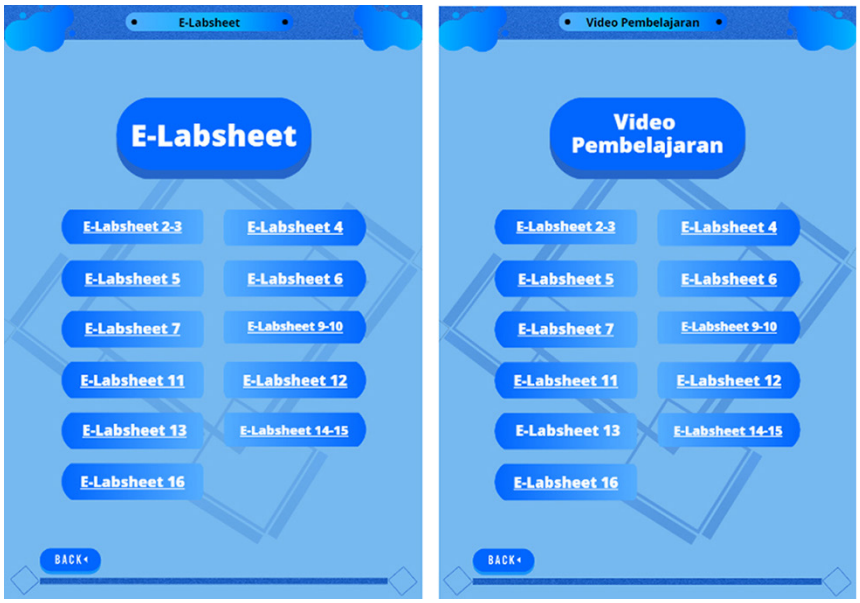

Fig. 4. E-LabSheet main menu

Then in Figure 5, we can see how the video tutorial process is played. Learning videos run very well on E-LabSheet, but the video quality is highly dependent on the quality of the user's device's internet network.

Fig. 5. E-LabSheet: playing videos

3.2 Validation

Media aspect. As explained in the method section, this media was validated by 3 experts. The media was validated from the media and material aspects using a validation test sheet. The following are the results of expert validation from the media aspect, which we summarize in Table 5 and Figure 6 below:

Table 5. Media aspect validation results

No.	Media Aspect	V1	V2	V3	Avg.
1	Quality and Appearance	32	31	32	31.67
2	Interactivity	34	34	33	33.67
3	Navigation	30	29	31	30.00
Total					**95.33**

Each media aspect consists of 20 positive and negative statements, with a maximum score of 5 and the lowest score of 1. The total maximum score of the three aspects is 100.

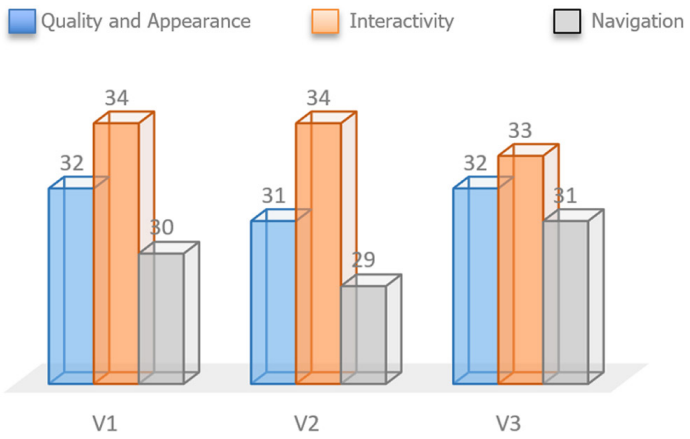

Fig. 6. Media aspect validation results

Material aspect. In Table 6, we can see and interpret that the material aspect is the same as the previous media aspect, which is categorized as valid with a total validation score of 90.67.

Table 6. Material aspect validation results

No.	Material Aspect	V1	V2	V3	Avg.
1	Content	31	30	31	30.67
2	Readability	30	31	30	30.33
3	Material Presentation	30	30	29	29.67
Total					**90.67**

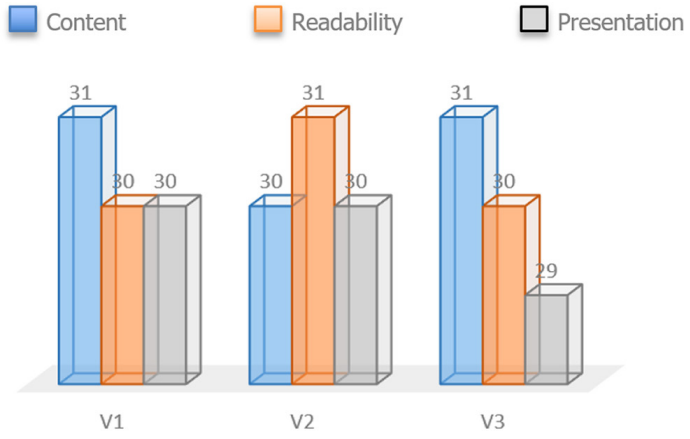

Fig. 7. Material aspect validation results

In Figure 7, it can be seen that there is no significant difference in the assessment of the assessment by 3 experts on the 3 aspects of the material being assessed.

3.3 Media practicality

To be able to measure the practicality of the media, previously valid media were distributed to users, namely students, then an assessment questionnaire was distributed about the practicality of using media, then also measured how students responded to the media that had been developed. Here, the questionnaire is distributed online using a google form to all students who have taken the computer network practicum course. A total of 134 students filled out the questionnaire. In this study, we calculated everything to find out how the responses and responses from users to the media we developed. The following are student responses regarding the E-LabSheet media in Figure 8:

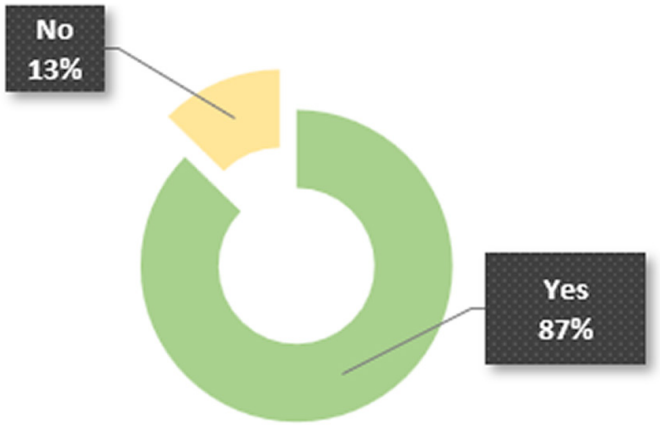

Fig. 8. The results of student responses

From the data obtained, it is known that 87% of students answered yes or agreed about some positive statements in the questionnaire. These results mean that the development of the E-LabSheet media received a good and positive response from students. However, there were some inputs given by students through comments and suggestions, including 1) More varied practice questions, not multiple choice; 2) The video size is reduced so that the video playback process can be better and smoother.

3.4 Learning outcomes

Class A. Learning outcomes are measured by calculating the final score (combined mid-exam with final exam scores). Class A is a class that is not provided by E-LabSheet. Class A consists of 15 students. The students' mid and final exam results are shown in Figures 9 and 10. It is known that there are still 7% of students whose scores are low. Most of the students' scores were in the mid-range.

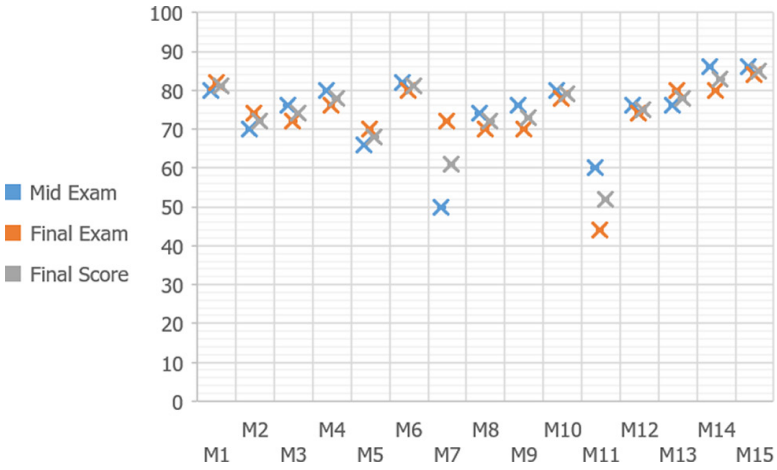

Fig. 9. Student exam results (Class A)

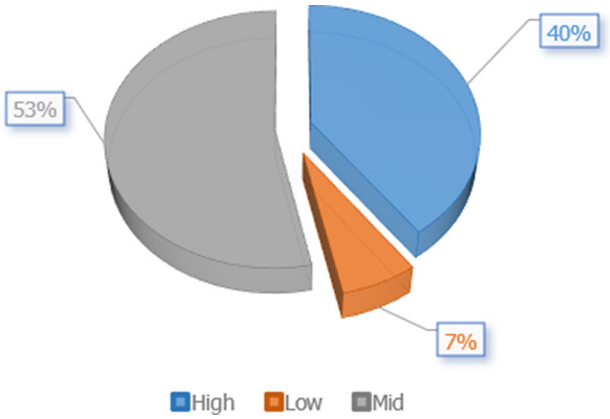

Fig. 10. Student exam results (Class A) by the range

Class B. Class B learning outcomes show different results from class A. In class B, students are given E-LabSheet to support practicum activities. Based on the results of the mid and final exams, the results of class B are as follows:

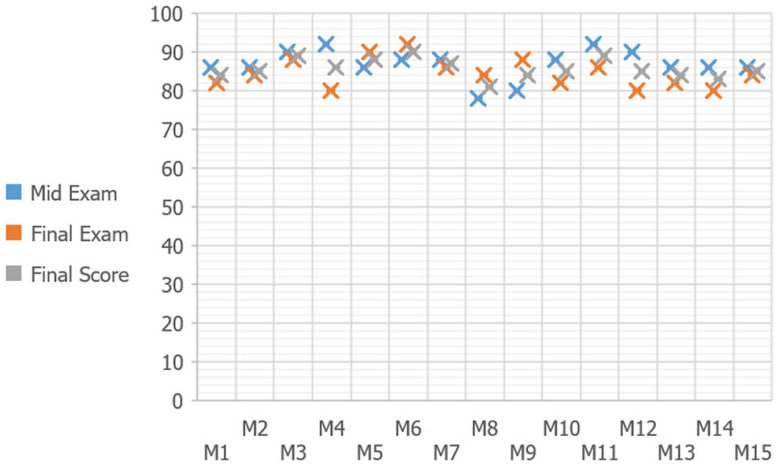

Fig. 11. Student exam results (Class B)

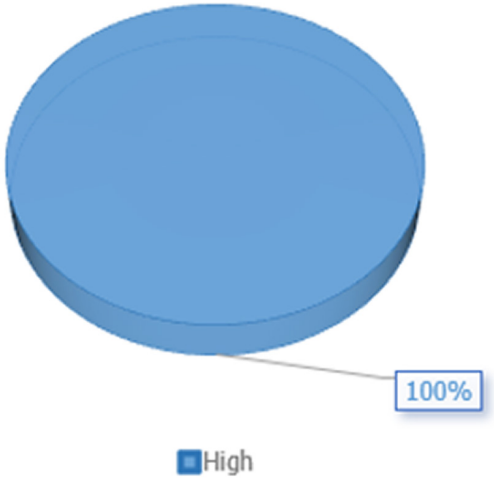

Fig. 12. Student exam results (Class B) by the range

In Figures 11 and 12, we can see that the final scores of all class students are above 75. This means that, as explained at the beginning, scores above 75 are categorized as high. Class B is the class that was given the treatment, and the results were in line with what was expected. It is proven that the student scores are much better.

3.5 Discussion

To measure the effectiveness of this medium, we compared the learning outcomes of two different classes, A and B. In detail, the comparison of the two can be seen in Figures 13 and 14 where from 15 students from each class, there is a very significant

difference. It can be interpreted that the use of E-LabSheet based on 4Cs is able to give better results in class B. The average learning outcomes of class B are better than class A, with an average final score of class B reaching 85.67, while class A is 74.13. There is a difference of 11.54. So, it can be said that this media, as a complement to learning, is able to increase learning outcomes by 16%.

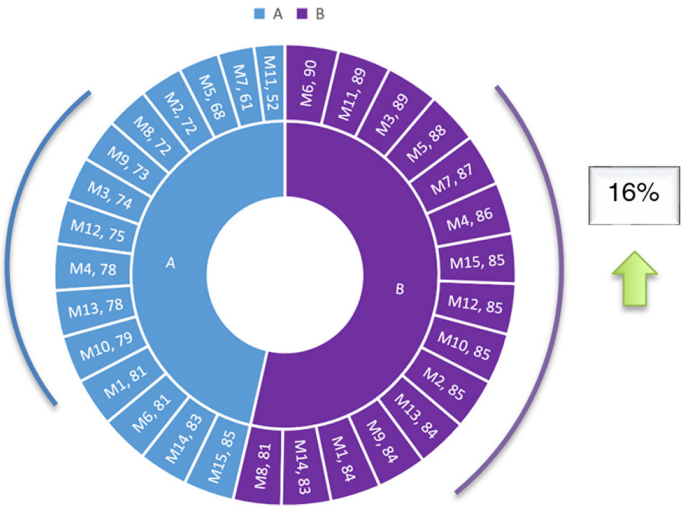

Fig. 13. Comparison of learning outcomes for class A and class B

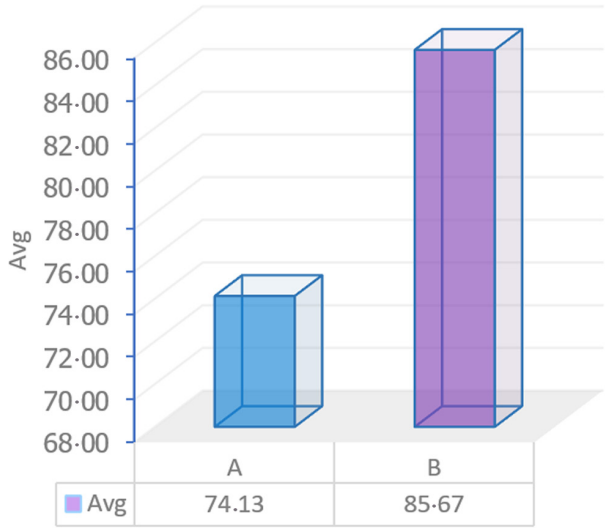

Fig. 14. Comparison of the average final scores of class A and class B

The results of this study prove that learning media is a tool that can help the teaching and learning process so that the meaning of the message conveyed becomes clearer and the goals of education or learning can be achieved effectively and efficiently [23]–[25]. Effective learning certainly requires good planning, also supported by good learning facilities and media. Likewise, the selection of media to be used in learning must consider the characteristics of the course, learning styles, learning objectives, facilities, and infrastructure. Of course, various types of media will not be used simultaneously in learning activities. For this reason, it is necessary to select the media. As mentioned by Arsyad, the criteria that need to be considered in the process of selecting learning media include: a good learning media must be clear and neat in appearance; Includes text, images, sound, and video. Unattractive media will reduce students' motivation in the learning process; Learning media must be adjusted to the number of targets; relevant to the topic being taught; In accordance with the learning objectives; practical, and flexible [26].

4 Conclusions

From the results of the research we obtained, we can conclude that learning media can clarify the presentation of messages and information so that they can simplify and improve learning processes and outcomes. Learning media can increase and direct students' attention so that it can lead to learning motivation, more direct interaction between students and their environment, and the possibility of students learning independently according to their abilities and interests. We have also succeeded in developing E-LabSheet media that can support computer network practice activities by loading 4C's skills which are implemented in problem-based practice where students practice analyzing, evaluating, and designing their own computer networks. So that students, before entering the laboratory, already have better knowledge. The results we obtained are also very good, where the developed E-LabSheet is valid, practical, and effective, proven to be able to improve student learning outcomes with an average percentage of 16%. It is evident from the results of the comparison between class A and class B in the results and discussion it is clear that learning outcomes B, which were given special treatment, gave better learning outcomes than class A. It is hoped that the results of this study can be used as a reference for further research for the development of media that will be better in the future. The weakness we encountered in the development of this E-LabSheet is that this media is very dependent on the quality of the internet as responded by students as users, especially when playing high-quality videos requires a stable and fast internet connection. We also conclude that learning media will be effective if used in the right environment, right on target, then teachers or lecturers, and students are also expected to use the media well.

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Design, Implementation, and Evaluation of Online Bioinformatics and Neuroinformatics Labs

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Abstract—In recent years, online laboratories have become highly integrated into the educational process due to the development of distance learning tools as well as circumstances associated with the Covid-19 pandemic. As part of a master's degree program in bioinformatics and neuroinformatics, in the academic years 2020–2021 and 2021–2022, the mandatory module "Laboratory Education (LE)" included 9 labs which transitioned to online delivery. A questionnaire was administered to all participants examining their self-reported learning as well as their satisfaction with each lab, the educational material associated with each lab, as well as the facilitator in each lab. A total of 73 postgraduate students completed the questionnaire. According to the results, the overall satisfaction from each laboratory ranged from 3.94 to 4.49/5.00. Furthermore, there is a variety of values in self-reported learning ranging from 23 to 50/50. Finally, although 7 out of 10 students indicated they are satisfied with the distance structure of LE, 8 out of 10 say they prefer LE to be carried out with a physical presence in the labs.

Keywords—online labs, virtual labs, remote labs, bioinformatics, neuroinformatics, self-reported learning, postgraduate students, satisfaction

1 Introduction

Bioinformatics and Neuroinformatics are fast growing scientific sectors, attracting large investments, and offering excellent employment opportunities to graduates. In fact, postgraduate studies in Bioinformatics and Neuroinformatics offer high career prospects in many innovative and pioneering scientific fields [1]. In addition, postgraduate studies have the potential to engage students with research in these important scientific fields.

Laboratory experiences offer an added value to the education of students in Bioinformatics and Neuroinformatics and are usually part of the academic curriculum [2]. Specifically, Laboratory experiences are valuable because they allow students to learn about the scientific method, including experimental design, data collection and analysis as well as ways of using data to draw conclusions. Thus, gaining laboratory

experience is a necessary component of postgraduate programs in these fields, as they help students develop their research skills while simultaneously preparing them for the labor market [3].

The Master's Degree Programme "Bioinformatics and Neuroinformatics" which is offered by the Hellenic Open University in collaboration with Ionian University focuses explicitly on preparing graduates for careers in bioinformatics and neuroinformatics. Specifically the program has three inter-related objectives: a) promote the scientific knowledge and development of primary scientific research in the fields of biomathematics (applied mathematics, modelling and simulation of systems), bioinformatics (genomics, proteomics, biomarker discovery, drug design, systems biology, programming languages for biology), computational biology, neuroinformatics and neurosciences (biomedical signal and image analysis, biomedical data processing, knowledge mining, development of algorithms); b) provide high-level training and expertise in research methodology, including conducting and analyzing clinical studies, processing and interpreting biological data, designing applications for decision making, developing models for diseases' prognosis and diagnosis, and engaging in meta-analysis of biomedical data; and c) prepare qualified graduates for successful careers in both academic and research environments, as well as in biotechnology companies, pharmaceutical industries or computing and research companies, both nationally and internationally. In addition to coursework, the program is reinforced with laboratory education, which is open to all students after completion of the first semester of studies. Laboratory education ("Lab Education" from now on) is compulsory, is not weighted by grades, and requires physical presence at the Laboratory of Bioinformatics and Human Electrophysiology at the Ionian University (BiHELab).

However, the sudden shift to online education due to the pandemic has resulted in the need to adapt labs for virtual delivery. In this context, "Lab Education" for the academic years 2020–2021 and 2021–2022 took place online. In this study, we first present the framework and content of "Lab Education" and how it was delivered in the academic years 2020–2021 and 2021–2022. We subsequently explore students' a) satisfaction concerning the activities within each lab, b) self-reported learning from each lab, c) satisfaction concerning the equipment of each lab, d) satisfaction concerning the material provided for each lab, and e) satisfaction concerning the facilitators of each lab. Finally, we present the findings from this work, limitations of the research, and conclusions.

2 Lab Education

2.1 Bioinformatics and neuroinformatics principles

The online "Lab Education" of the master's degree program "Bioinformatics and Neuroinformatics" lasted ten (10) days. Specifically, "Lab Education" included a total of nine (9) labs as well as a special session related to entrepreneurship in Bioinformatics. The equipment of the Bioinformatics and Human Electrophysiology

Laboratory at the Ionian University was used for the labs. The duration of each lab was approximately 4 hours.

The activities associated with each of the 9 labs focused on bioinformatics and neuroinformatics topics. More specifically, *Lab 1* was concerned with the detection of antigenic epitopes in cytological smears, recognizing the application of automated methods for the detection of antigenic epitopes in cytological smears, and the evaluation of the nuclear or cytoplasmic expression of the applied antibodies at the cellular level. *Lab 2* focused on determining the principles of photonic microscopy using inverted fluorescence microscopy. In *Lab 3* students used a particle sizer to evaluate the Single Particle Optical Sizing method for measuring the size of a large number of particles and construct the actual particle size distribution in a mixture. In *Lab 4*, students worked with databases and performed high-scale data analysis using supervised and unsupervised learning methods. In *Lab 5*, students had the opportunity to study and analyze protein tertiary structures using appropriate libraries and online databases. In *Lab 6*, students used an electronic microscope with a built-in chemical analyzer, to identify the principles of electronic microscopy. Then, in *Lab 7* students utilized a real-time Polymerase Chain Reaction thermal cycler, to explain real-time polymerase chain reaction and techniques for analyzing its results. In *Lab 8*, students utilized behavioral analysis software, electroencephalography (EEG), and biomarkers recording equipment in the context of neuroeducation and neuromarketing topics. Finally, *Lab 9* focused on databases and bioinformatics tools, to find homology and multiple alignments and use tools for in silico protein analysis.

Lab Education concluded with a session on "Entrepreneurship in bioinformatics and neuroinformatics, Career prospects". Table 1 presents the labs, equipment used, description of activities, and expected learning outcomes.

Table 1. Labs Education

Lab	Equipment	Description	Skills Learned
Lab 1: Detection of antigenic epitopes in cytological smears.	Automated immunohistochemistry (immunocytochemistry) machine for the detection of antigenic epitopes, microscope with accompanying equipment for image evaluation, processing, and storage.	Application of automated methods for the detection of antigenic epitopes in cytological smears and the evaluation of the nuclear or cytoplasmic expression of the applied antibodies at the cellular level.	Use of immunocytochemistry for research, diagnostic and therapeutic purposes.
Lab 2: Photonic microscopy.	Full inverted fluorescence microscope. Complete system for acquisition and analysis of imaging data type easyRatioPro.	Basic principles of photonic microscopy.	Proper use of the instrument; Collection and observation of microscopic organisms; Observation of peripheral blood.

(Continued)

Table 1. Labs Education *(Continued)*

Lab	Equipment	Description	Skills Learned
Lab 3: Particle Sizing Systems AccuSizer 780SIS.	Single Particle Optical Sizing System.	Method for measuring the size of a large number of particles, one at a time, and constructing the true particle size distribution (PSD) in a mixture.	Compare methods for measuring the size of a large number of particles.
Lab 4: High-scale molecular biology data analysis using supervised and unsupervised learning methods.	Weka and Matlab Software.	Data mining and analysis. Data preprocessing. Contribution of unsupervised learning with appropriate data.	Develop classification and prediction models; Generate data from molecular biology; Develop Clustering and Visualization Algorithms.
Lab 5: Analysis of tertiary protein structures.	Bio3D library, R and Rstudio.	Understanding and analysis of protein tertiary structures.	Predict protein structure using online methods; Evaluate protein structures.
Lab 6: Electronic microscope and online tools.	Table electronic microscope with built-in chemical analyzer EDS.	Basic principles of electronic microscope and its applications.	Proper use of the instrument; Analysis of samples.
Lab 7: Real-Time PCR – DNA amplification.	Real-time PCR thermal cycler C1000 Touch thermal cycler chassis.	Basic principles of real-time polymerase chain reaction and techniques for analyzing its results.	Identifying how to amplify specific regions of the genetic material; Correlate DNA changes with the diagnosis of pathological conditions.
Lab 8: Behavioral analysis software.	Observer XT and FaceReader, BeneVision N22/N19, Mindray.	Using observer and face recognition software and monitor of observing subjects.	Identifying how behavioral analysis takes place using software and hardware.
Lab 9: Databases and Bioinformatics Tools.	–	Nucleotide, amino acids, biological molecules. Bioinformatics databases for DNA and RNA.	Operate basic bioinformatics tools for homology finding and multiple alignments; Use tools for in silico protein analysis.
Entrepreneurship in bioinformatics and neuroinformatics, Career prospects.	Entrepreneurship opportunities in bioinformatics and neuroinformatics.	Recognize entrepreneurship opportunities in bioinformatics and neuroinformatics.	–

2.2 Pedagogy of online labs

Lab activities empower students to learn and practice, while simultaneously increasing motivation and leading to a positive attitude towards the course [3]. Despite the promise of lab education, the cost of the lab equipment is usually high. Due to limitations in the availability of equipment, traditionally there was a need for students to share the equipment while conducting physical labs. Further, to address resource constraints, each group performed the experiments only once. The Covid-19 pandemic made it necessary to replace traditional labs with virtual labs [4], helping address some of the limitations associated with physical labs. Online laboratories, for instance, are not nearly as costly to run compared to traditional laboratories [6]. Therefore, the shift to virtual delivery, addressed issues around the availability of equipment and provided opportunities to perform the lab multiple times. Further, virtual labs helped eliminate students' fear of making mistakes offering opportunities to repeat as needed. Finally, virtual labs facilitated independent learning and provided flexibility to students in terms of space and time, particularly for students who had difficulties commuting and attending a traditional lab away from their homes [8].

In the context of this work, the design of the online labs was consistent with principles of distance education and efforts to strengthen self-regulated learning [5]. The delivery of the online labs was facilitated through the learning management system students used in their coursework. A combination of synchronous and asynchronous learning activities was used to achieve the goals. Specifically, emphasis was placed on the educational process and the pedagogical use of the lab equipment. During the educational design, clear learning objectives were determined that guided the development of educational material and interactive lab activities. The educational material followed pedagogical specifications to attract student interest and effectively support them in the learning process, while conducting the labs independently. This approach was successful by matching the theoretical training students had already acquired from the modules they had completed with the laboratory training they were offered. At the same time, the educational material provided opportunities for active participation, formative feedback, and self-evaluation. From a design point of view, a key consideration also focused on ensuring that labs were designed to be equitable for all, regarding the means and labs' objectives [7].

3 Research approach

A quantitative research design was employed to examine students' perceptions of the virtual labs. Specifically, upon completion of the laboratory exercises associated with the 9 labs presented above, including the special session on entrepreneurship, a questionnaire was sent to all students who participated in "Lab Education". The questionnaire was developed by the research team and was aligned with dimensions of high quality lab education. Specifically, the following five quality dimensions (criteria) were defined and used for each lab (See Figure 1).

1. Students' satisfaction concerning the educational activities within each lab;
2. Students' self-reported learning from each lab;

3. Students' satisfaction concerning the equipment of each lab;
4. Students' satisfaction concerning the material made available to them from each lab;
5. Students' satisfaction concerning the facilitators of each lab;
6. Students' overall satisfaction with each lab considering all the above.

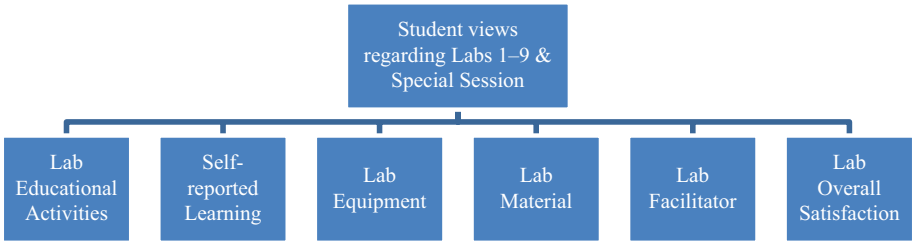

Fig. 1. Structure of quality dimensions

Moreover, the questionnaire included questions regarding student satisfaction concerning a) their interaction in the Labs; b) the educational approaches (e.g., constructivist) that were used in Labs; c) the design of "Lab Education" (e.g., tools and resources that were used); and d) time spent studying during the "Lab Education" program. Finally, the questionnaire asked students to indicate their overall satisfaction with the distance "Lab Education" program as a whole and register their preference between physical and virtual labs. Specifically, the online questionnaire included five parts:

1. Instructions on how to fill out the questionnaire.
2. Likert scale questions focusing on the five quality dimensions of virtual labs. For this purpose, a five-point Likert scale was used which ranged from "Totally disagree" to "Totally agree" or "Totally satisfied" to "Totally dissatisfied".
3. Questions concerning the virtual labs and the distance learning approach.
4. Demographic data.
5. An open-ended question at the end of the questionnaire where students could make suggestions concerning lab improvement. The results from this question are not presented in this work.

The questionnaire was distributed to all 98 students who completed the labs during the academic years 2020–2021 and 2021–2022. The questionnaire was administered each academic year, after the completion of the "Lab Education". A total of 73 students fully completed the questionnaire, representing a return rate of 74%. Of those, 40 participants (56%) were males, and 29 (40%) were females. Three respondents chose not to respond to the gender question. The majority of the respondents, 47 (65.0%), had no previous experience with laboratory education. Further, 55 (76%) did not experience technical problems with online labs. Table 2 presents the profile of our sample.

Table 2. Students' demographic profile

Demographic	Description	No	Percentage
Gender	Male	40	56%
	Female	29	40%
Previous experience with Lab Education	Yes	25	35%
	No	47	65%
Experienced technical problems	Yes	17	24%
	No	55	76%

Data were analyzed using descriptive and inductive methods. Additionally, we employed the capabilities of statistics and machine learning to mine our data. Specifically, we applied dimensionality reduction techniques to reduce the complexity of our data, offering visualization schemes that facilitated more efficient data analysis. Towards this end, we applied the principal component analysis (PCA) [9] and the t-distributed stochastic neighbor embedding (tSNE) method [10] in examining the data. Both techniques transform the initial data dimensionality into a lower-dimensional data space while preserving the pairwise sample distances as much as possible. More specifically, PCA projects the initial data onto a new subspace keeping most of the variance among the data points. The tSNE is an extension of the stochastic neighbor embedding method trying to transform the pairwise data similarities into joint probabilities.

4 Results

4.1 Student satisfaction and self-reported learning

Based on the descriptive statistics, the mean of students' satisfaction was measured. Means ranged from 3.92/5.00 to 4.58/5.00. In particular, the satisfaction per laboratory (Figure 2) was measured. The results show that the Data Analysis (Lab 4) and PCR Labs (Lab 7) offered students the highest level of satisfaction (4.40/5.00). In contrast, the AccuSizer Lab (Lab 3) had the lowest satisfaction score (3.92/5.00), followed by the Photonic Lab (Lab 2) (4.14/5.00).

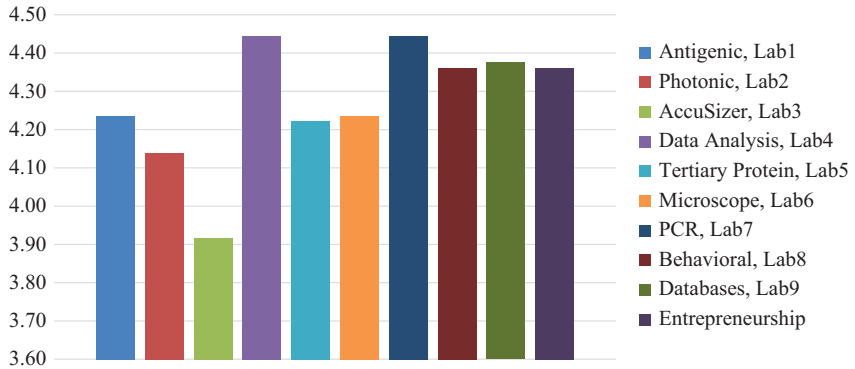

Fig. 2. Mean of students' satisfaction with each Lab

Concerning self-reported learning from each lab, (Figure 3), students indicated that they received more satisfaction with knowledge acquired from the Data Analysis Lab (Lab 4) (4.36/5.00) followed by the DataBases Lab (Lab 9) (4.33/5.00). In contrast, the AccuSizer Lab (Lab 3) had the lowest level of satisfaction with knowledge acquired (3.92/5.00), followed by the Photonic Lab (Lab 2) (4.01/5.00).

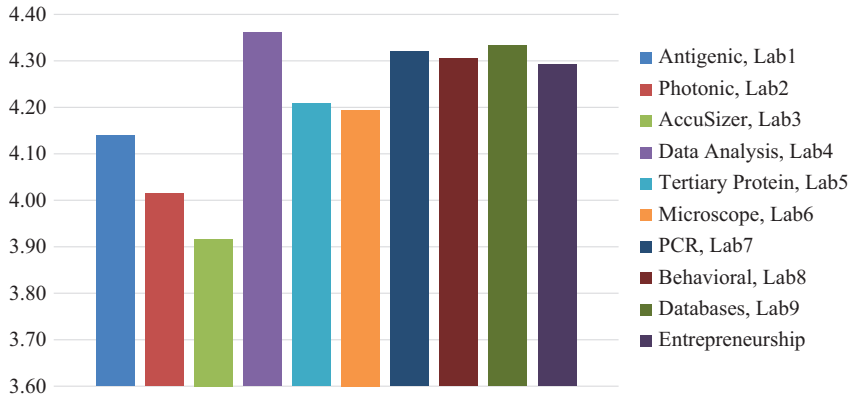

Fig. 3. Mean of students' satisfaction with knowledge acquired in each Lab

Regarding the equipment of each laboratory (Figure 4), the two labs with the highest satisfaction scores were the Databases Lab (Lab 9) (4.40/5.00) and Data Analysis Lab (Lab 4) (4.35/5.00) which are the two labs with no-physical equipment at the Laboratory of Bioinformatics and Human Electrophysiology at Ionian University. The only equipment required for these labs is a computer and the corresponding software, which students also have on their digital devices. The lowest satisfaction scores were associated with the equipment of the Photonic Lab (Lab 2) (4.01/5.00), followed by the AccuSizer Lab (Lab 3) (4.04/5.00). The special session on entrepreneurship had no equipment because the facilitators simply gave a lecture and answered questions.

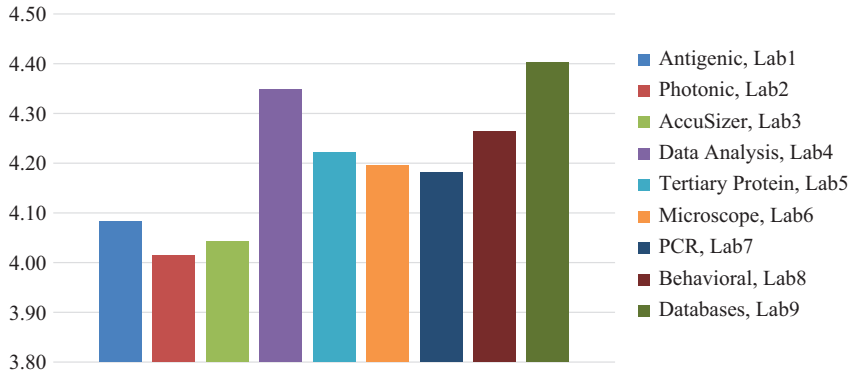

Fig. 4. Mean of students' satisfaction with equipment in each Lab

Regarding the materials students were provided for each laboratory (Figure 5), Databases Lab (Lab 9) (4.40/5.00) and Data Analysis Lab (lab 4) (4.35/5.00) offered students the highest satisfaction. In contrast, the AccuSizer Lab (Lab 2) had the lowest level of satisfaction (3.97/5.00), followed by the Photonic Lab (Lab 2) (4.07/5.00).

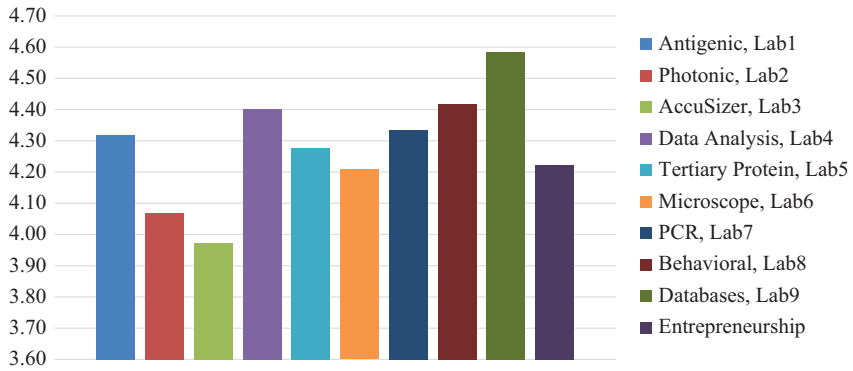

Fig. 5. Mean of students' satisfaction with material in each Lab

Regarding the facilitator in each lab (Figure 6), students indicated more satisfaction with the facilitators in the Behavioral Analysis Lab (Lab 8) (4.58/5.00) followed by the DataBases Lab (Lab 9) (4.51/5.00). In contrast, students reported the least satisfaction with the AccuSizer Lab (Lab 3) (4.25/5.00), followed by the Photonic Lab (Lab 2) (4.31/5.00).

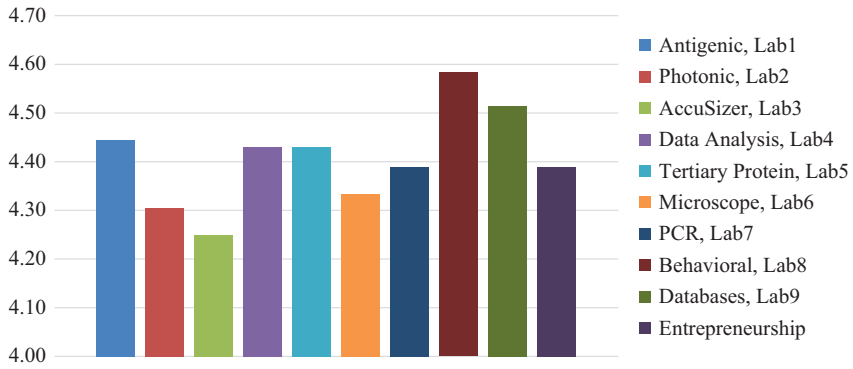

Fig. 6. Mean of students' satisfaction with facilitator in each Lab

Finally, the students' overall satisfaction with each lab is presented in Figure 7. The boxplots show the overall satisfaction of all participants for each lab. As shown in Figure 7, most of the participants rated all the Labs with a high grade. The Entrepreneurship special session had the highest score (4.49/5.00). This lab was unique in that it provided information to students about the labor market and successful startups in the biomedical industry. Given widespread concerns among students about their future academic and employment prospects, this session helped introduce students to future

opportunities in their fields. The Databases Lab (Lab 9) also enjoyed high satisfaction while (4.42/5.00) the AccuSizer Lab (Lab 2) demonstrated the lowest level of overall satisfaction (3.94/5.00) followed by the Microscope Lab (Lab 6) (4.11/5.00).

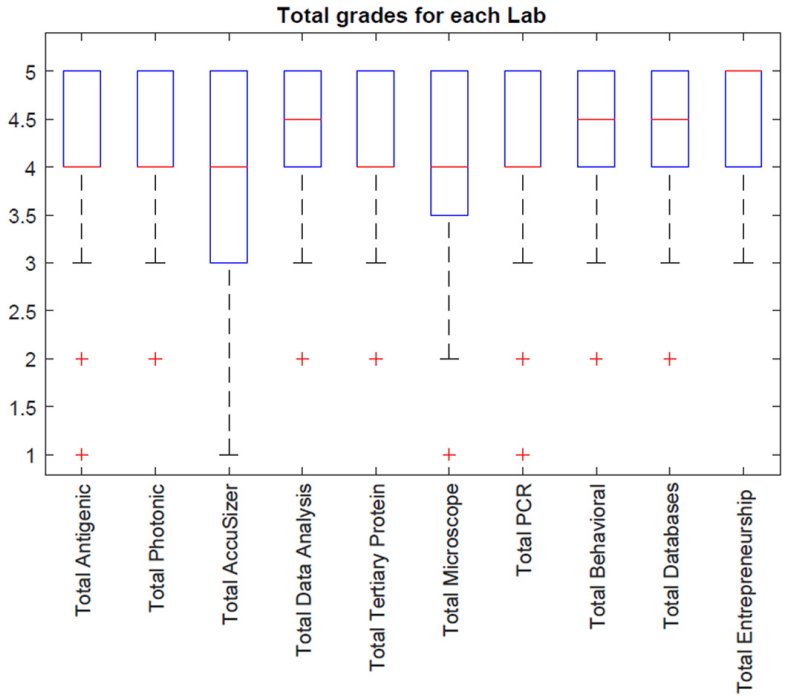

Fig. 7. Boxplot with students' overall satisfaction with each Lab

In addition to recording their satisfaction to specific lab dimensions, students were also asked to indicate their satisfaction concerning a) their interaction in the Labs; b) the educational approaches (e.g., constructivist) that were used in Labs; and c) the design of the "Lab Education" (e.g., tools and resources that were used). Results are presented in Table 3.

Table 3. Students' satisfaction with the distance education approach

Satisfaction Concerning	Description	No	Percentage
Interaction in the Labs	Satisfied	46	63.89%
	Neutral	15	15.28%
	Dissatisfied	11	20.83%
Educational approaches used in Labs	Satisfied	44	61.11%
	Neutral	17	23.61%
	Dissatisfied	11	15.28%
Design of the "Lab Education"	Satisfied	59	81.94%
	Neutral	9	12.50%
	Dissatisfied	4	5.56%

As noted, an additional question focused on how frequently students studied during "Lab Education". The results are presented in Figure 8. The majority of students, 41 students (58.33%) did not report studying, or studied just 1 or 2 times during the 10 days of the "Lab Education".

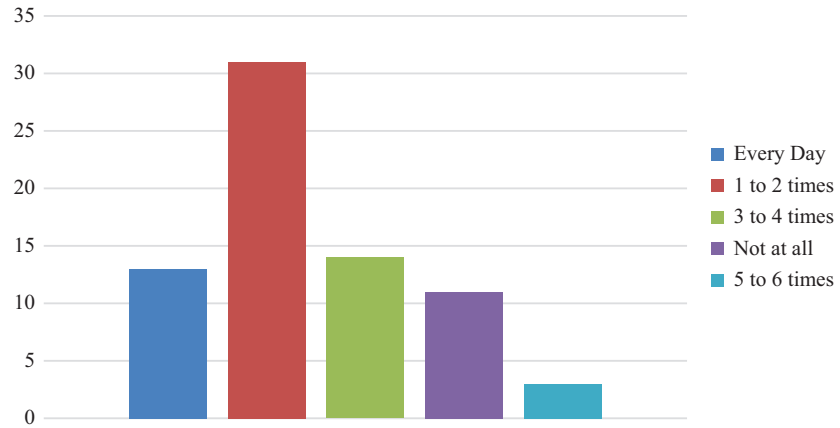

Fig. 8. How often did the students study during "Lab Education"?

4.2 Overall satisfaction and preference between physical and virtual labs

The two last questions concerned students' overall satisfaction with the "Lab Education" program as a whole and their views between online and physical labs.

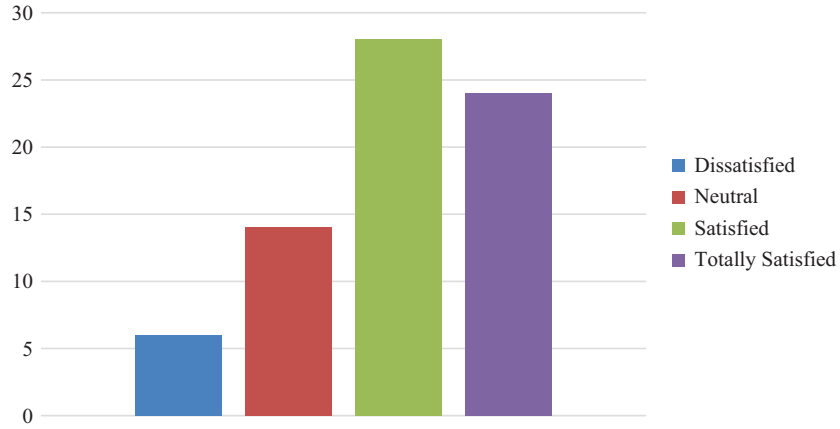

Fig. 9. Students' overall satisfaction concerning the "Lab Education" program

As shown on Figure 9, 7 out of 10 students, (72.22%) declared that they are satisfied with the "Lab Education" program. Importantly, no student declared that was totally dissatisfied. Nonetheless, 8 out of 10 (79%) students declared that they preferred labs with physical presence instead of virtual labs (Figure 10).

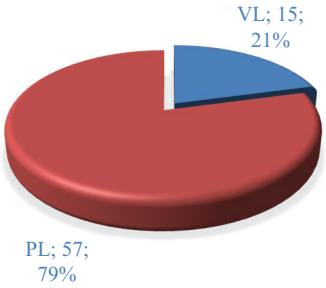

Fig. 10. Students' preference concerning virtual labs (VL) or labs with a physical presence (PL)

Additionally, the correlation among the students' overall satisfaction for all Laboratory pairs is highlighted below (see Figure 11), offering noteworthy results. The pairwise linear correlation coefficient between each pair of labs is utilized, while the values 1–10 in the heatmap correspond to the respective Lab 1–Lab 9 and the special session on entrepreneurship. The strongest correlation is observed between Lab 1–Lab 2, and Lab 6–Lab 2, while the lowest, is observed between Lab 4–Lab 7 and Lab 4–Lab 10.

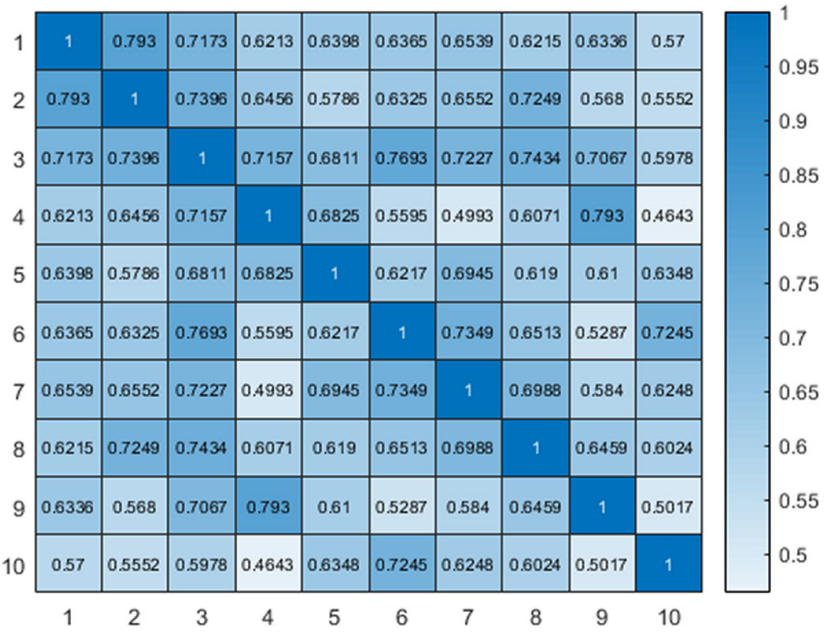

Fig. 11. Heatmap with the correlation among the students' overall satisfaction for all Laboratory pairs

With the application of the principal component analysis (PCA) [8] and the t-distributed stochastic neighbor embedding (tSNE) method [9], we tried to mine knowledge regarding the impact of gender and the previous laboratory experience on students' answers. Using two well-established dimensionality reduction algorithms, we reduced the

60-dimensional space (6 questions for 10 Labs) to a 2-dimensional space (see Figures 12 and 13), offering a visualization framework by coloring each student (circle shape) with his/her gender and previous laboratory experience. The visualization schemes show that both classes are not separable. Hence, the students' answers do not differ significantly according to their identified gender or previous laboratory experience.

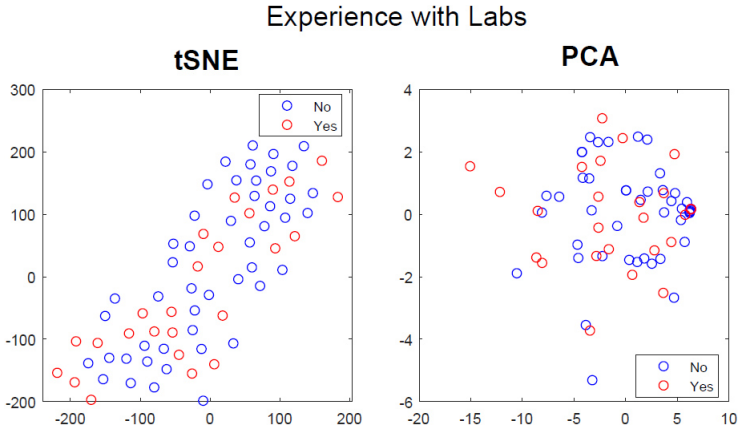

Fig. 12. 2D Visualizations with the laboratory experience impact all students' answers using the tSNE and PCA dimensionality reduction methods

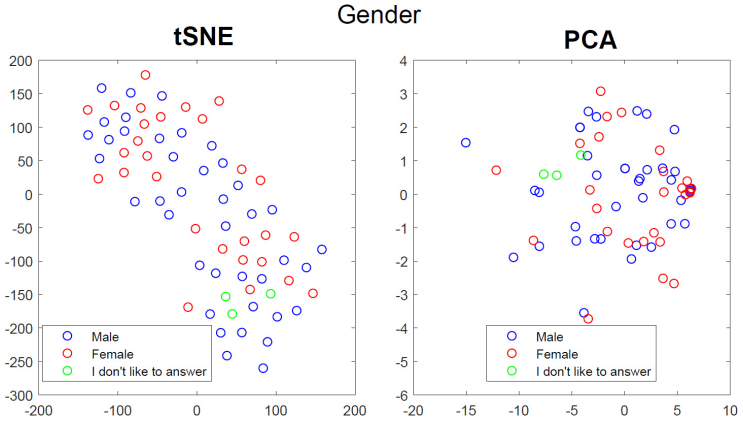

Fig. 13. 2D Visualizations with the gender impact in all students' answers using the tSNE and PCA dimensionality reduction methods

5 Discussion

In this research, we presented the "Lab Education" module of the Master's Degree Programme in "Bioinformatics and Neuroinformatics" which is offered by the Hellenic Open University in collaboration with Ionian University in Greece. Moreover,

we examined students' self-reported learning from each lab as well as satisfaction related to the educational activities, the equipment of each lab, the material made available for each lab, and the facilitators of each lab. Additionally, we examined overall satisfaction with the "Lab Education" component of the program and student preferences regarding physical versus virtual labs. Finally, we correlated these results with demographic data and questions regarding the "Lab Education" module.

Students' overall satisfaction concerning each lab was high, as the mean ranged from 3.94/5.00 to 4.49/5.00. Additionally, the total satisfaction concerning the "Lab Education" program as a whole was also high as 7 out of 10 students were satisfied with it. Nonetheless, 8 out of 10 students indicated that they would prefer to be in the laboratory with physical presence during the lab exercises. This finding is not surprising as this was students' first exposure to virtual labs. It is possible that this finding is related to the applied orientation of "Lab Education". "Lab Education" included several experiments and literature indicates that students have difficulties with performing experiments in virtual environments [8, 11]. The majority of the students expressed preference in completing the experiments/exercises in a laboratory with a physical presence. The high satisfaction rate, however, shows that students can cope with a combination of labs, with a physical and online presence.

Findings also indicated that no statistical differences were observed between gender, first-level undergraduate degree, overall satisfaction with the "Lab Education", previous experience with laboratories, and all other variables of the survey. This finding indicates that the virtual "Lab Education" has the potential to reach all students regardless of gender or background knowledge. This finding is noteworthy because the Master's Degree Programme in "Bioinformatics and Neuroinformatics" enrolls students from different undergraduate majors (biologists, computer scientists, mathematicians, clinicians, etc.). Thus, results indicate that the program has the potential to reach students from various backgrounds.

"Lab Education" included a variety of equipment (hardware and software) to carry out the experiments. Some labs had exercises that needed a computer (students had their own device) and free and open software [12, 13], while others had only special equipment without any software. This feature had an impact on both student satisfaction and self-reported learning [14, 15]. Specifically, laboratory topics that did not include biological experiments documented higher self-reported learning and students indicated a high degree of satisfaction. On the contrary, specific laboratory exercises (for example microscopes and biological analyses) received lower satisfaction scores. This finding is likely related to student preference for physical labs and the need to perform the experiment on their own instead of just attending a demonstration of it.

As a final note, it is important to mention, that there are some limitations of this research that should be considered. First, the research was conducted on a module of a specific Master's Programme in Bioinformatics and Neuroinformatics, which meant that the results cannot be generalized to other relevant contexts. Secondly, the students were not divided into groups according to their background characteristics. Lab support from the facilitator was provided in accordance to the principles of differentiated instruction, which may have varied across facilitators. Thirdly, the sample is relatively small, so results should be treated with caution.

6 Conclusions

The goal of this research was to examine student perceptions regarding the "Lab Education" module of the Master Programme in Bioinformatics and Neuroinformatics, which was to take place with physical presence, but due to the Covid-19 restrictions, transitioned to online delivery. Results indicated high students' satisfaction with the program, the facilitators, and the components (equipment, material) of the lab module. Students also declared positive self-reported learning outcomes.

Despite students' high satisfaction, a very large number of students (8 out of 10) stated that they prefer "Lab Education" with physical presence in the laboratories, which highlights that these online laboratories require further design and teaching techniques, that will allow students a more authentic remote experience. This finding merits further research so that students can experience and take part in laboratory education from their own space, using appropriate digital technologies. This approach will enable students to feel confident that they participate in a laboratory environment that enhances their knowledge and understanding, their practical skills, their perception, their analytical skills, and their social and scientific communication with other students and researchers.

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An Ethereum Private Network for Data Management in Blockchain of Things Ecosystem

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Abstract—The advent of blockchain technology in the development and design of smart internet of things (IoT) systems offers the opportunity to secure and transfer data flow, preserve its integrity, and provide transparent mechanisms for its management. Blockchain has actually attracted applications in vital fields because it provides many advantages over centralized database such as traceability, confidentiality, availability and trust. A private network offers the most secure and peer-restricted environment for big data flow, specifically in IoT ecosystems. An integrated blockchain-IoT ecosystem in which three Raspberry Pi 4 nodes communicate and interact in a closed loop to control smart applications via an Ethereum platform in a secure and an efficiently emulated environment is piloted. The proposed blockchain of things (BCoT) ecosystem adds a new layer to the physical, network and application layers of a typical IoT architecture. The concept of a fully decentralized private Ethereum BCoT network may find applications in several fields that call for the removal of single-point of failure and ensures data integrity and transparency.

Keywords—blockchain, IoT, Ethereum, private, smart system, big data

1 Introduction

The Internet of Things (IoT) has become one of the most powerful emerging technologies that integrate big data, cloud computing and machine learning, into one melting pot that converge the physical and digital worlds together and create a truly data-driven digital society. The size of the IoT market was valued at $190 billion in 2018 and is expected to reach $1.1 trillion by 2026, while the number of IoT connected devices were 8.4 billion in 2017, reached 29 billion in 2021, and expected to rise to 35 billion in 2025, and possibly 500 billion IoT devices in 2030 [1]. A wide range of IoT products and objects such as appliances, furniture, clothes, machines, food packages home security sensors, remote educational labs, wearable medical devices, and industrial IoT devices and systems represent an internet node that interacts with the human environment [2]. In fact, IoT has already been widely adopted in many smart applications, mainly at homes [3], cities [4], factories [5], hospitals [6], farms [7], agriculture [8], transport [9], civil services and governance [10] and weapons [11], to name a few.

However, the nature of IoT centralized infrastructure in which sensors, actuators, devices communicate and exchange data without the need for human intervention makes it vulnerable to attacks and hacks [12]. In addition, it is difficult to ensure security and privacy of the generated big data efficiently. Data sharing between devices in IoT networks may experience falsified authentication and trust due to the heterogeneous sensor types that may lead to increased scope for sharing erroneous, inaccurate, or inconsistent data, and hence inaccurate models built from this data [13]. In addition, the IoT ecosystem faces several challenges such as heterogeneity, diversity of technologies and requirements, limited access to the real devices, protocol fragmentation, releasing regular updates, programming, and handling failures, as well as common pitfalls and bugs that IoT developers and practitioners encounter [14].

In the development and design of smart IoT systems, blockchain technology provides the natural means for secure data management that ensures its transparency and preserves its integrity [15]. In fact, blockchain has emerged in the last decade as one of the most important pillars of the disruptive technologies of the fourth industrial revolution. Its main features have attracted many applications in several fields such as banking, government, business, agriculture, health, transport, logistics, and education, to name a few. In fact, blockchain technology offers many advantages over centralized database solutions such as decentralization, security, transparency, traceability, confidentiality, availability, and trust [16]. According to a Gartner report, the convergence of blockchain and IoT has recently been viewed as the sweet spot of two powerful technologies [17] that were otherwise facing their demise and extinction within 20 years. In fact, issues related to security and management of the massive amount of big data generated by IoT devices rendered the technology inefficient and economically insignificant. However, the integration of the two emerging technologies has led to the launch of a new concept of blockchain of things (BCoT) [18], a term first coined at the IoT Festival 2018 in Australia. The new alliance of BCoT is anticipated to provide proper security infrastructure by leveraging cryptographic blockchain for IoT, which is already showing its limitations and deficiencies, thus, may solve IoT's most pain points [19].

In this paper, a private blockchain of things network, based on Ethereum platform, is developed, and integrated into three IoT sensors and devices units, each connected to Arduino microcontroller and Raspberry Pi 4 minicomputer in order to create a proactive and autonomous ecosystem. Communication and exchange of data between the IoT units is established in an interactive manner where each device makes appropriate decisions independently according to predefined conditions determined by the surrounding environment. The ultimate purpose of system design and adaptation is to demonstrate its viability in strategic, practical and real-life applications.

2 Blockchain and IoT integration

IoT devices are usually susceptible to cyber-attacks because of their limited capacity, storage, and computing processors. In addition, security, privacy, and reliability of big data generated by IoT devices face several challenges that may be resolved using blockchain in complementing the IoT paradigm by providing trusted and secured data and enhancing latency and transparency [20]. Furthermore, IoT may be further

integrated with cloud computing infrastructures to increase systems storage and processing capabilities. One of the main features of blockchain is its ability to eliminate the need for a central authority to store transactions and records in identical copies in decentralized servers within the network. Simultaneously, authentication of data is carried out using a consensus algorithm while analysis is performed using smart contracts [20]. Blockchain further supports communication between IoT units directly, thereby bypassing central servers and allowing faster exchanging of messages and data among nodes. In addition, blockchain guarantees trust and authenticity of IoT information as all nodes keep a copy of verifiable data. Furthermore, security is always ensured, as cryptography is a main pillar of blockchain structure, and the use of hashing algorithms to connect chains forms the basic mechanism of blockchain operation.

The integration of blockchain technology in IoT applications may be traced back to the IBM platform on "Autonomous Decentralized Peer-To-Peer Telemetry" or ADEPT, which advocated for the concept of a decentralized approach that offers greater scalability and security for the IoT [21]. Several surveys were recently conducted on the topic of blockchain and IoT integration, which covered a multitude of methods and models pertaining to many situations and solutions [22–29]. For example, the implementation of a decentralized autonomous organization (DAO) using smart contracts written in Solidity on the Ethereum blockchain to automate organizational governance and decision-making was described for individuals working together collaboratively outside of a traditional corporate form [30].

Xiao, et al introduced a new architecture for IoT task offloading and resource allocation in smart homes, factories, and hospitals. The architecture consists of device layer, a distributed agent controller and a hierarchical edge-computing server that integrates the blockchain in the middle layer to ensure the integrity of transaction data [31]. Sharma et al used a three-layer distributed cloud model utilizing fog computing to manage raw IoT data stream at the network edge and cloud level [32]. On the other hand, Moinet et al presented a security protocol and decentralized model based on blockchain in order to provide cryptographic keys and trusted data storage for wireless networks, thereby enabling various components to authenticate data about every network peer [33].

A method to collect, store and retrieve data from IoT devices and sensors using blockchain in a secure, authentic and decentralized fashion was developed as a testbed on private Ethereum along with a low-cost Raspberry Pi in order to test the feasibility and performance of blockchain-based secure IoT system [34]. The encrypted data was stored in Inter Planetary File System (IPFS) or Swarm while PKI provided data authentication and confidentiality and all keys are securely stored in TPM and locked into Raspberry Pi. TPM provides secure key management, cryptographic functions, and disk encryption [34]. Accordingly, Fernando et al carried out experiments with IoT devices and blockchain technology to merge low-cost Raspberry Pi minicomputer devices with Ethereum platform, yielding promising outcomes when applied in pharmaceutical industry [35]. Furthermore, a blockchain-IoT based system was developed to detect the rice stock in orphanages using mobile application. The system was designed to collect data generated from a Raspberry Pi sensors connected to the network, thereby offering service providers, donors and rice suppliers the ability to track system operations such as rice financial transactions and shipping items to the orphanage, and hence reduce transaction manipulation and amplify transparency [36]. On the other hand,

a blockchain-based emergency service was implemented in a smart home system to handle the access control among untrusted public services and smart home IoT devices [37]. The system consisted of a Raspberry Pi as a tool to gather data from the home sensors and Ethereum platform. The solution is supported by web applications for home users and for staff of home service providers supervising the entire operation. In addition, the system incorporates an IPFS database to handle the generated files from the smart home, thus inherently enabled to prevent DDoS attacks. An Ethereum blockchain-based web-interface solution to handle the facilitation of renewable energy transactions in an effortless and efficient way was also proposed as a solution that describes the ability to perform energy transactions in near-real time from a prosumer to consumer without the need of a central authority [38]. On the other hand, Devi et al proposed a design architecture for satellite monitoring by merging IoT and blockchain that resulted in a new architectural framework, which enhanced security and data transparency through the implementation of consensus algorithms to predict various satellite performance parameters [39]. Numerous other applications of the marriage between blockchain and IoT can actually be found in the literature.

3 Standard IoT ecosystem

The basic IoT architecture consists of physical or perception layer, network layer, and application layer as depicted in Figure 1. At the physical layer lies the hardware sensors, actuators and devices that act as an interface with the physical world of the IoT ecosystem. These eventually share information and exchange data with each other using various communication and internet messaging protocols such as radio-frequency identification (RFID), message queuing telemetry transport (MQTT), advanced message queue protocol (AMQP), wireless sensor network (WSN), Bluetooth and ZigBee, and Wi-Fi. Routers, switches, and firewalls are deployed as gateways at the network layer in order to communicate with one another and with application platforms such as computers, remote-control devices, and smartphones as well as to transmit data from IoT devices to cloud servers such as Google, Amazon, IBM and Microsoft Azure for storage and analytics purpose. The communication or network layer performs functions related to gateway, routing and addressing, message, publishing and subscribing, flow control and reliability and QoS, and hosts the IoT web portal. All decisions related to communications and measurements of the flow and its quality and energy consumed are made in this layer. With the advent of 5G technology, faster connectivity makes it suitable for low-powered IoT sensors, while Internet Protocol version 6 (IPv6), which comes with large addressing space, makes it a desirable communication protocol for IP enabled smart devices.

On the other hand, the application layer is responsible for delivery of various applications to different users in different industry segments such as healthcare, manufacturing, smart cities, food, logistics, retail, environment, public safety and drug. In fact, the application layer encompasses specific service support and contains common capabilities that can be used by different IoT applications, where all actions related to the control, security and management of the application are made such as QoS manager, device manager, business process and execution, authorization, key exchange and

management, trust and reputation, identity management. A services layer performs functions such as service storage, composition, organization and orchestration, virtual entity resolution and monitoring. All decisions related to the monitoring, storage, organization and visualization of the received information, including resolving virtual entities created are made. An improved and reliable seven-layers IoT architecture that takes on all functions of the traditional architecture has recently been introduced [40].

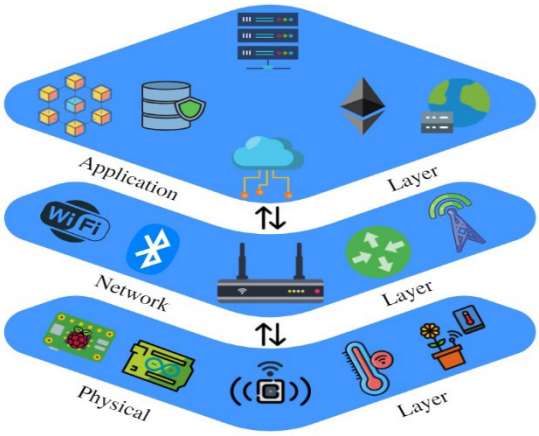

Fig. 1. Basic three-layered IoT architecture

4 Standard blockchain technology

Blockchain is a sequence of blocks linked together in an ecosystem that encompasses a wide range of applications as it employs complicated encryption techniques to verify transactions as shown in Figure 2. When transactions are validated through mining, a new block is added to the chain and the miner is rewarded with the crypto-currency associated with that blockchain. In fact, mining is the process of conducting complex computational mathematics, specifically complicated cryptographic computations that need a significant amount of computing power and capacity to complete [25]. The miners' task is to check the legitimacy of payments and add the approved transactions to the network. The process in which the miner starts working to solve the complicated cryptographic computations is called Proof of Work (PoW), when a miner solves the PoW, other miners tend to check the validity of that solution, and then the blockchain nodes validate the block to be added to the chain.

Ethereum, in particular, is an open-source blockchain platform that can access the data stored in the chain to read and write. An Ethereum network can also run in a private mode to restrict permissions to specific users. Only the nodes with the right permissions will be able to access the blockchain while being isolated from the main network. The Ethereum platform utilizes smart contracts to simplify transactions and to store data. Smart contracts are compiled into Ethereum Virtual Machine (EVM) byte code and ABI definition using Solidity, which supports the characteristics of a modern scripting language, including static typing, inheritance and complicated user-defined data types.

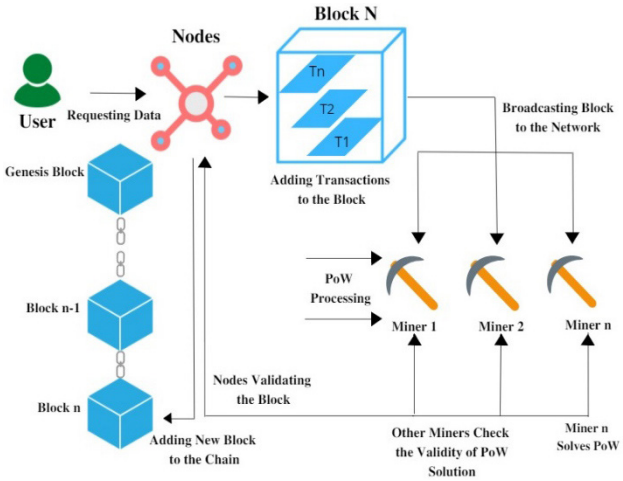

Fig. 2. Transaction block validation and addition flow

Proof-of-Work (PoW) is a consensus algorithm deployed in cryptocurrency transactions in such a way as to calculate a certain hash value of the block header to gain the right to append a new block to the chain [41]. Every block has a unique hash that is used in the calculations of the PoW algorithm. When a block is ready to be appended to the blockchain, every field of the header is filled except the first nonce. The nonce value is the solution of a mathematical problem [42]. One node would broadcast the block to other nodes once it reaches the target value and all other nodes would then mutually confirm the correctness of the hash value. When a miner completes a task, the block is verified by other nodes in the network. The hash function has the property that the verification can be performed fast comparing with PoW calculations. Reducing the complexity of proof of work is needed in IoT systems to obtain a shorter time to achieve consensus. If most of these nodes validate the PoW, the block is inserted in the chain copies of each node within the system. In case that more than one miner completes the PoW at the same time, a fork in blockchain appears. Future-validated block will be inserted in the longest chain and the remaining chain will be lost [43]. The consensus mechanism used in Ethereum is a variant of PoW, which has the same principles as PoW.

Ethash is a Proof of Work (PoW) algorithm based on hashing designed to resist ASIC and to avoid problems of computing power centralization and mining resource centralization caused by the emergence of ASIC in Bitcoin, which to some extent alleviated the problem of mining centralization [44]. The main feature of this algorithm is that it consumes the entire available memory access bandwidth; hence making memory reads the bottleneck of the whole computation process. This high load is based on using a large data structure called DAG, during mining [45]. If the number of correctly calculated Ethash function values for a given clock frequency turned out to be less than the number of correctly calculated Ethash function values for a lower frequency, then the experiment can be considered completed [46]. Ethash includes three main sub-functions: first, Keccak512 with its input is the header and the nonce concatenated

into a string of length 320 bits. The length of the output is 512 bits, and this result will be the input for the next sections. The second is a loop, which consists of two parts; the first consists of 64 loops, each of which consists of fetching data from the DAG file and using the FNV function to compute the required values, while the second part calculates the cmix value from the mix value. The third sub-function is Keccak256 with its input taking the form of hexadecimal string concatenated from the Keccak512 result and the cmix from the loop has a length of 768 bits [47]. However, a proof of authority (PoA) consensus protocol was practically implemented on an existing IoT-blockchain system, followed by a performance analysis based on different solutions procedures [48]. The implementation investigated the issues that affect the integration of blockchain and IoT like latency and network stability, demonstrating an increase stability in the block period of the PoA Ethereum network. Proof of Work (Ethash) consensus algorithm was eventually chosen over Proof of Authority (Clique) because it supports the mining process needed for smart contracts migration and later transactions.

5 Proposed blockchain of things system

There are many forms of architecture to integrating blockchain with IoT. A system is proposed to integrate blockchain technology into an IoT ecosystem in order to deal with big data generated by sensors and devices. Integration of blockchain technology in IoT is useful for data immutability, privacy, transparency, decentralization, authentication, preserving confidentiality, integrity, and availability. In fact, blockchain grants IoT devices independence as they lack autonomy outside of their centrally managed networks. On a blockchain network; however, each node has a unique private and public key pair that identifies it as an independent participant on the network. Specifically, the keys are enforced largely using cryptographic signatures or digital messages that unmistakably recognize the sender. Thus, each node makes its own decisions and uses its own resources independently of other nodes. Consequently, the network becomes secure as it removes the situation of a single point of failure [49]. The system focuses on building a private Ethereum network to benefit from the full transparency, privacy, network restrictions, decentralization, and security features that are also present in public networks but not as fully integrated as in private networks. In addition, private blockchain networks allow IoT communication with the blockchain without restrictions, which is a valuable alternative to all the machine-to-machine protocols [50].

A private Ethereum network was constructed using Go-Ethereum client, forming a blockchain layer on top of the three standard IoT layers as shown in Figure 3. A pilot system which consists mainly of three IoT units as nodes and a windows miner node was constructed, where the blockchain layer plays as a middleware with the application layer [26]. The system consists mainly of three IoT units as nodes and a windows miner node. Each of the IoT units consists of a Raspberry Pi 4, Arduino UNO R3, and multiple sensors connected to the Arduino. The Arduino is connected to the Raspberry Pi serially, where a Python script is used to retrieve the big data generated by these multiple sensors and stored in the Raspberry Pi 4.

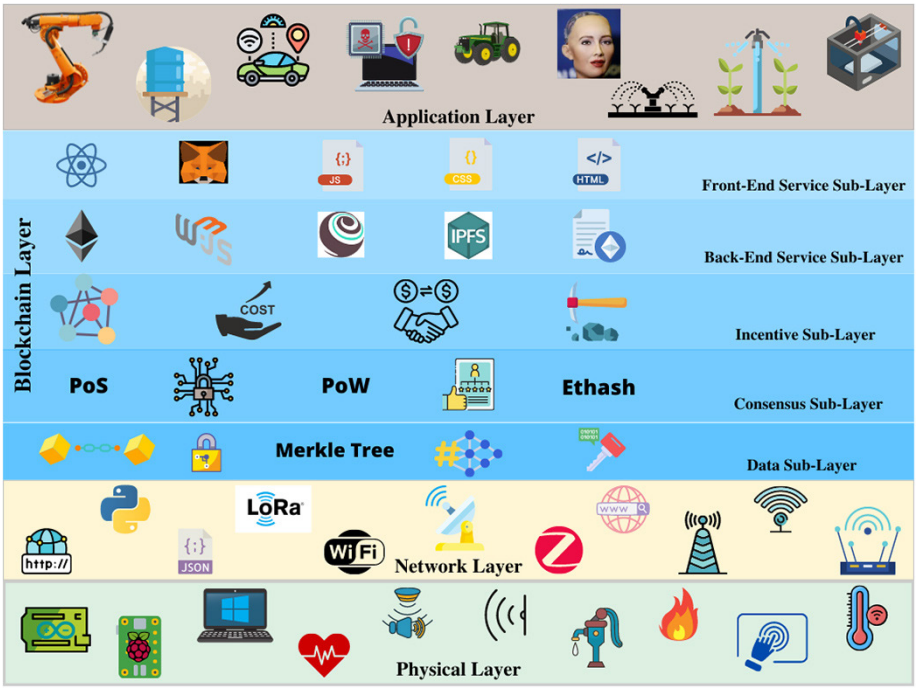

Fig. 3. Private Ethereum blockchain of things ecosystem architecture

The Arduino is connected to the Raspberry Pi serially, in which a Python script is used to retrieve the big data generated by these multiple sensors and stored in the Raspberry Pi. Communication in the physical layer between IoT devices including Raspberry Pi and Arduino is established using a simple Python code as demonstrated in the code below, while a screen shot of implementation of the physical layer is shown in Figure 4.

```
import serial
if __name__ == '__main__':
ser = serial.Serial('/dev/ttyACM0, 9600')
ser.flush()
while True:
   if ser.in_waiting > 0:
      line_s = ser.readline().decode('utf-8')
```

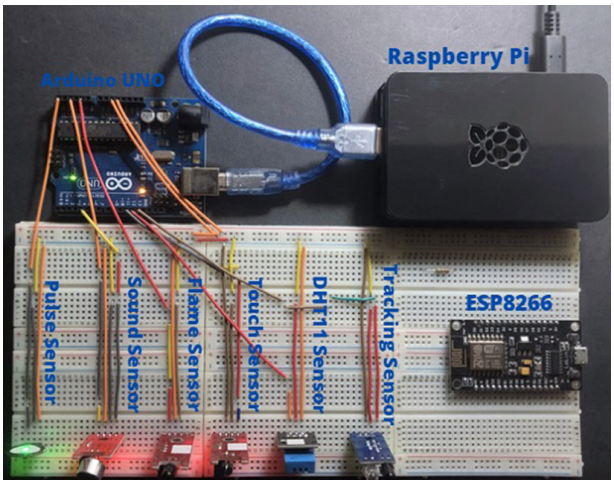

Fig. 4. Screen shot of the physical layer implementation

The blockchain layer actually consists of five sub-layers, which offers services such as application programming interfaces (APIs), data collection from IoT physical layer, and encryption of data with digital signature using various algorithms and hash functions depending on the blockchain platform [26]. For example, BTC blockchain chooses SHA-256 as the hash function and ECDSA as the signature algorithm. The network sublayer is essentially an overlay P2P network running on top of the communication layer. The overlay network consists of either virtual or physical links connecting nodes in the underlying communication networks. One node only simply broadcasts the block of transactions to its connected peers. Once receiving the block of transactions, other peers will verify it locally. If it is valid, the block will be further propagated to other nodes through the overlay network.

Consensus sublayer is mainly involved with the distributed consensus for the trustfulness of a block. Various consensus algorithms like PoW, PoS, PBFT, and DPOS can achieve the consensus. The block propagation mechanisms are the prerequisite for the distributed consensus protocols. The incentive sublayer is responsible for digital currency issuing and distribution; designing reward mechanism especially for miners; and handling transaction cost. The service sublayer provides users with blockchain-based services for various industrial sectors including manufacturing, logistics, supply chains, food industry and utilities. The blockchain as a service (BaaS) can be achieved by smart contracts, which can be automatically triggered when a special event occurs. The network sublayer that is established on top of the communication layer is the abstraction of underneath communication networks, consequently offering a universal network access across different networks as shown in Figure 3.

The second layer, referred to as the backend of the system, is built to handle, store, and manipulate big data generated by the IoT units. A Solidity smart contract was written to retrieve the big data from each Ethereum IoT unit node, and then deployed using truffle framework, to install truffle, node.js and node package manager (npm) are needed. Web3 is the latest version of the web, and it is programmed using JavaScript language. The Web3.js is needed to communicate with the Ethereum IoT unit nodes because the Ethereum nodes only speak JSON RPC language, which is only understood by Web3.js.

On the other hand, Inter Planetary File System (IPFS) is integrated as a decentralized storage for the big data generated. The front end was programmed using ReactJS, JavaScript, HTML, and CSS to be a user-friendly decentralized application. If users request access to that DApp, MetaMask is needed to connect their Ethereum account to the DApp. Zheng et al have actually proposed an IPFS-based blockchain data storage model to solve the problem of high demand on space and bandwidth and to synchronize data with the bitcoin network [51]. Evidently, the data size and compression ratio is greatly reduced, its security performance enhanced and synchronization speed improved because of utilizing the characteristics of the IPFS network and the features of its hash. In addition, Hasan et al proposed an IoT-blockchain based solution using IPFS to transfer large-size streaming data in a decentralized, transparent, traceable, reliable, secure, and trustful manner [52]. In this way, IPFS offers an appropriate alternative for big data storage as the transfer process preserve its privacy and confidentiality through a proxy re-encryption network. In fact, an IoT-IPFS framework was evaluated experimentally and proved feasible utilizing a Raspberry Pi minicomputer, hence demonstrating the advantages of P2P decentralized storage infrastructure [53].

6 Programming smart system applications

The data generated by the sensors connected to Arduino will flow according to a code that controls operations within an infinite loop as shown in Figure 5. The Arduino keeps receiving data as long as the sensors are functioning appropriately. These sensors are distributed over the three IoT test units that monitor and measure a number of physical quantities such as temperature, humidity, pressure, flame, pulse, sound, colour, and tracking in both analog and digital forms. Specific messages are generated and displayed with each corresponding sensor and updated every ten seconds as long as the Arduino is connected to the Raspberry Pi, and both are on, up and running.

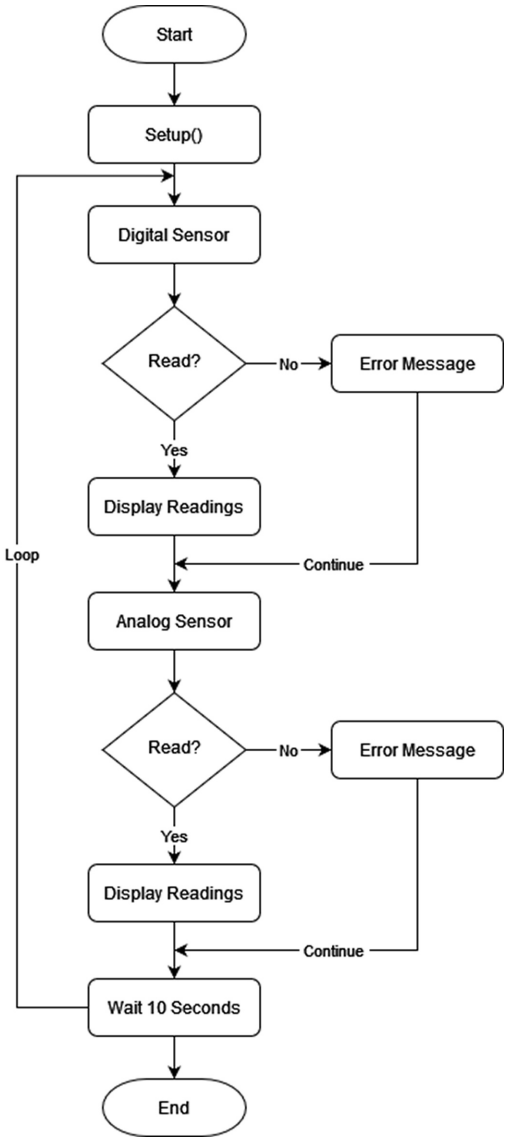

Fig. 5. Flowchart of system operation

The smart contract is migrated and deployed successfully using Truffle framework as depicted in the example of the Solidity code below:

```
contract BlockchainofThings {
  struct IoTUnit {
    string id;
    string hum;
    string temp;
    string touch;
    string fire;
    string pulse;
    string sound;
  }
  mapping(uint256 => IoTUnit) public IoTUnits;
```

When the migration is complete, a message, which indicates that the migration is being saved to the chain and some useful outcome for later use, will appear. The outcome shows the smart contract address in hexadecimal format, node account public address, block timestamp and number. In addition, the cost, Eth balance in that node account, gas used and price which is equal to 1 gwei (according to Ethereum.org glossary: gwei is short for gigawei, a denomination of ether, commonly utilized to price gas. 1 gwei = 109 wei. 109 gwei = 1 ether). This migration can be executed using truffle with the command: pi$ truffle migrate—reset.

> contract address: 0x9F16613350983E57c98F8263D7A3319142c7BbdE
> block number: 193
> block timestamp: 1649136742
> account address: 0xe3FE4957561E7C13614A25ed17fDbed4BA9096D0
> gas used: 929516 (0xe2eec)
> gas price: 1 gwei
> Total deployments: 2
>Final cost: 0.001121459 ETH

The smart contract creation was submitted after deploying it using truffle on the node exhibiting its address, hash in hexadecimal format, and zero nonce value in the node as shown in Figure 6. The figure also shows the peer count participating in this Ethereum private peer-to-peer network, which is the windows miner node. If adding other nodes in the network, the peer count will increase. To add any peer to the network, the java script console command (Admin.addPeer (enode address)) may be used. Consequently, to determine the enode of any specific node, the java script console command (Admin. nodeInfo.enode) is used. The smart contract is then migrated on the Raspberry Pi node, and the submission is reflected on the windows miner node, hence displaying a new sealing work commit, indicating that a potential block was mined, and that the transaction fees to create the smart contract is executed.

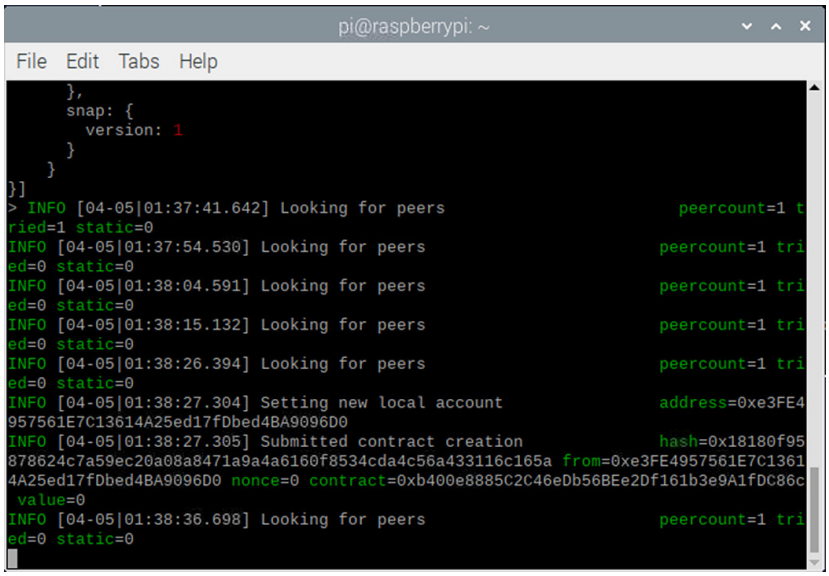

Fig. 6. Smart contract creation reflected on Geth node

Additionally, when running the miner node on Windows using Go-Ethereum (Geth), the command used should specify the database in which the chain data will be stored. Then, enable http, considering http APIs that will be used such as ether, miner, web, and personal APIs, unlock miner account address with its pass phrase, and define the CPU threads will be used in mining. The result will display the block number and hash, seal hash, gas used as shown in Figure 7. The miner node will keep mining and the block number will keep increasing as long as the miner node is running. Eventually, when the block is successfully mined, the miner will be rewarded, thus presume mining a new block.

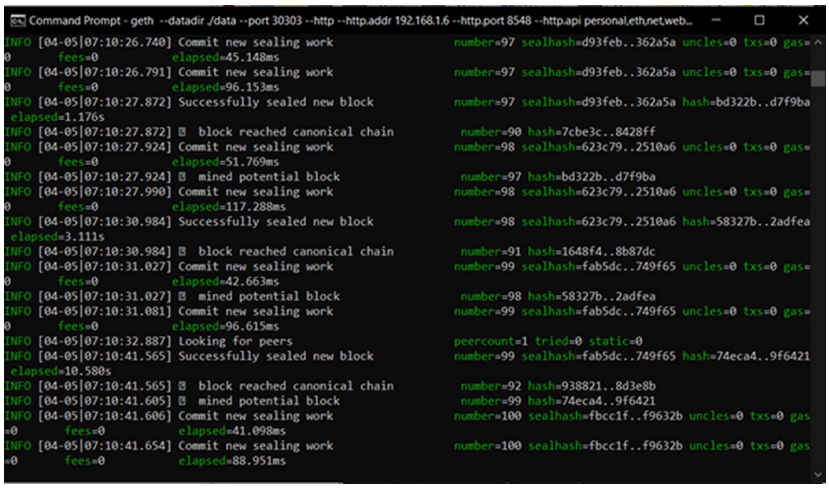

Fig. 7. Data mining procedure on the windows miner node

IPFS was installed on each Raspberry Pi for later use in data storage in a hashed way, a step that will improve the performance of data storage and security mechanism. The data will actually be encrypted and stored in IPFS in a decentralized manner. The official Go implementation of IPFS (Go-IPFS) was configured and initialized as shown in Figure 8, thereby enabling IPFS to function properly on each IoT node using the command $ipfs init daemon. In addition, the command $ipfs swarm peers was used to start looking and communicating with other IoT peers. The IPFS nodes uses bidirectional communication, as they listen (receive) and announce data at the same time using TCP and UDP protocols.

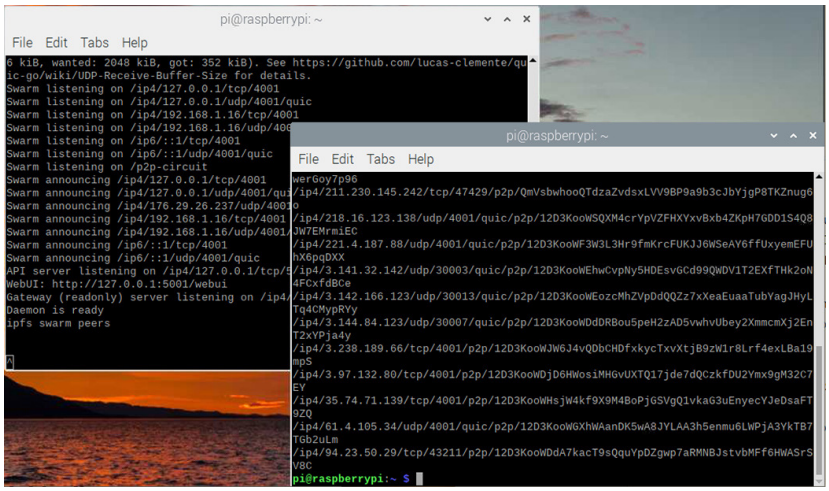

Fig. 8. IPFS running on Raspberry Pi

7 Results and discussion

A full-decentralized private Ethereum network was implemented with three IoT full nodes and one miner node. The network was operated with PoW algorithm which enabled each IoT node to act as an independent entity and to interact and communicate with each other over the blockchain. Appropriate smart contracts were migrated successfully on each IoT node, and the miner node was able to mine the blocks of big data chunks generated by the sensors and devices, hence establishing a holistic high performance decentralized application (DApp). The DApp was initially designed as a public network; however, as IoT devices do not act as independent entities and need a way to connect and communicate with each other using socket programming or message queuing telemetry transport (MQTT) protocol, a private network was eventually chosen to realize the network. In fact, the private Ethereum blockchain network solution gives the DApp full decentralization, transparency and independence features. Consequently, IoT nodes acquire the ability to take independent unilateral decisions based on a predefined set of rules.

A client first converts each IoT unit into a full node in an Ethereum private blockchain network integrated with IoT. Go-Ethereum (Geth), the official Go implementation of Ethereum, was chosen for this purpose for its ease-of-use features. Each IoT unit was integrated with Geth to act as a full node, while connecting nodes together becomes necessary to act all as a private network. This, in turn, necessities the creation of a genesis block where a JSON file is initialized in each node. Puppeth tool was used for creating the genesis block that gives the option to choose between two blockchain consensus algorithms, Proof of Work (Ethash) and Proof of Authority (Clique). The Proof of Work algorithm was chosen as it supports mining, which is needed later for smart contracts migrations with the truffle framework. Puppeth is actually a very useful tool to generate the genesis block with prefunded Ethereum accounts and to determine the difficulty of the mathematical calculations made by the miner.

The implementation of a private blockchain network has actually been proven to be a very cost-effective solution because it leads to a decrease in the difficulty of calculations carried out by the miner compared to a public blockchain, thereby lowering CPU usage and reducing power consumption. At the same time, the utilization of a Raspberry Pi to act as a full Ethereum node is also cost effective, as it requires low power to operate efficiently, costs less than an actual computer yet acts as one. In addition, transaction fee is much lower in private Ethereum networks compared to public ones due to the reduced pressure on nodes requesting transactions. In addition, private Ethereum networks nodes perform tasks efficiently and rarely take up extra resources that slow down the platform, which is the case in public Ethereum network. Hence, private Ethereum networks enjoy attractive features such as stability and efficiency.

However, integrating blockchain in IoT is not a straightforward process because of high resource consumption, scalability, and processing time. Privacy and security in IoT are also challenging due to low resource capabilities and lack of standardization [54–55], which pose as a serious limitations for the proposed system. Consequently, security measures and practices were applied to the physical system, specifically to the Raspberry Pi by installing uncomplicated firewall (ufw) and Fail2ban software to configure each unit. In fact, Fail2ban software acts as an Intrusion Prevention System (IPS), which blocks any suspicious activity. Another limitation is power consumption of the PoW consensus algorithm, specifically when using Graphics Processing Unit (GPU) for mining. Fortunately, the proposed system utilizes CPU for mining, hence consumes less energy [56].

In IoT, one of the most popular integrated blockchain platform is Ethereum, although it was not designed especially for IoT. A private blockchain is a preferred option over a public one for implementation within a single organization due to its high efficiency, fast transaction speed, low cost, permissioned consensus and easy data handling and access [57–58]. In addition, Ethereum supports the use of private blockchain, which can be modified and utilized to fit in different IoT scenarios.

However, IOTA is another blockchain platform designed specifically for implementation in IoT devices. It is an open-source DLT that intends to provide a trust layer for IoT devices. IOTA has a unique data structure called Tangle, structured by directed acyclic graphs (DAG), which does not have blocks, only transactions, different from other DLTs such as Ethereum. IOTA has demonstrated its advantages in enhancing IoT applications' security and privacy. IOTA also adopts the PoW consensus algorithm,

which allows issuing transactions by approving previous transactions, then confirms their consistency and prevent spamming from malicious clients. A transaction with a proper nonce is allowed to attach to the Tangle, indicating that the PoW algorithm in IOTA is more lightweight than in Ethereum [59]. Both Ethereum and IOTA maintains a stable memory space usage. However, IOTA has a smaller memory usage than Ethereum while consuming more CPU resources and hence executing a smaller number of transactions than IOTA does.

8 Conclusions

A cost-effective and power-efficient private Ethereum network based on a number of Raspberry Pi nodes that control a smart application was designed and deployed in securely managed BCoT ecosystem. The private blockchain network was integrated with IoT devices to stream big data chunks generated by a large set of sensors connected to Arduino development board microcontroller and serially passed to the Raspberry Pi. The main purpose of this BCoT environment is to benefit from its features, including decentralization, transparency, privacy, and security. The BCoT concept may find applications in several fields that ensures data integrity and transparency and demand the removal of single-point of failure.

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Exploring the Issue of Parental Burnout with ICT's. How Do the Parents of Children with Disabilities Feel

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Abstract—The aim of this research was to investigate the level of burnout, depression, anxiety and stress experienced by parents with a child with disabilities in Greece. In particular, the negative emotional state is investigated, as well as the factors that may contribute to the appearance of parental burnout, anxiety, stress and depression. The dominant focus of the research is to emphasize the importance of the parental role, with the aim of improving parents' well-being and the development of their emotional and mental resilience. The sample involved 50 parents with children with disabilities. Data were collected using the online forms of questionnaires Parental Burnout Assessment & Depression Anxiety Stress Scale. The results showed that parents are prone to parental burnout, with the predominant dimension being exhaustion from parental role. The results showed that parents are prone to increased levels of stress, anxiety and depression, with the stress scale predominating. In addition in terms of statistics difference, older parents experiencing increased levels of parental burnout, as well as stress, anxiety and depression. Regarding the number of children in the family, a positive correlation was found only in terms of anxiety, as parents with more children seem to experience increased levels of anxiety compared to parents with one child. In conclusion, it seems that there are significant positive correlations among the levels of total parental burnout and its individual dimensions and the levels of stress, anxiety and depression.

Keywords—ICT's technology, parental burnout, anxiety, stress, depression, parents with children with disabilities

1 Introduction

It is very common for parents of children with a developmental disorder to suffer from anxiety, stress, fatigue, frustration, guilt and burnout. Until recently, the term burnout primarily associated with the emotional, mental and physical exhaustion, the frustration and the loss of interest that professionals feel. However, it is not only a feature of the work environment but it is also observed in other conditions that require

a closer relationship. Parental burnout and its consequences as severe exhaustion, emotional detachment and loss of all parental satisfaction, has received growing attention in international research [1]. Many children during the developmental period experience serious difficulties and need extensive care. Caring for a child with developmental disorders is differentiated by creating additional burdens to the parents due to functional difficulties, and make them feel unable to handle their children's difficulties. [2]. The burden of caring for a child with disability often heavily affects both parent's physical and mental health. According to research, parents of children with disabilities often experience higher levels of anxiety, depression and stress than parents of children without disabilities, regardless of the category of disability [3,4,5].

2 Parental burnout

In 2017, Roskam, Raes and Mikolajczak examined the parental burnout phenomenon. They investigated if the three dimensional structure of the syndrome occurs in a parental environment. They examined the specificity in relation to the professional burnout. [6]. The outcomes indicated the validity of a tri-dimensional burnout syndrome. The first dimension was depletion related to ones role as a parent. Another dimension was emotional detachment from their parenting role. Exhausted parents engage less and less in their parenting role. Parents` care are limited to daily functional aspects at the expense of emotional needs. They may, for example, enter an "automatic pilot", where they perform all the obligations related to children's care but feel emotionally numb, cannot relax and enjoy moments with their children. The third dimension was the feeling of incapability. Parents experience that they cannot handle the problems related to the children and their special needs [7]. Subsequently, researchers created the 'Parental Burnout Assessment' questionnaire, after collecting data from a sample of more than 900 parents. [6]. Parents' narratives indicate the four domains of parental burnout: exhaustion, contrast with previous parenting self, emotional burden, and resignation.

Studies that have taken place show that the number of parents with burnout has greatly increased in recent years. Conservative point prevalence estimates [6] suggest that at least 5% of parents have burnout, while according to a recently published international survey in 42 countries, the percentage of parental burnout in some countries reaches 8% [8]. The Covid-19 pandemic and the lockdown of parents with their children has exacerbated many of these factors, reducing also parenting resources and the possibility of early quality of life [9]. Research in Melbourne indicated increased parental burnout and especially higher rates in working parents with children in primary school [10].

Parental stress and exhaustion only lead down negative paths for all family. An international study in 42 countries examined the prevalence of parental burnout [11]. The outcomes have shown that the cultural context contributes to parental burnout arising. Thus, in non-traditional western cultures has displayed noticeably high rates

compared to more traditional contexts. Individualism and social isolation play a greater role in parental burnout than sociodemographic variables and parental fatigue from constant care of their child. According to research, parents' stress and exhaustion is linearly related to Euro-American mentality as a risk factor for parental burnout. The findings are in line with the observation of sociologists that parental care standards in Euro-American countries have become more and more demanding in the last decades [12], causing increasing psychological pressure on parents [13].

In contrast, life in a 'collectivistic' cultural environment can protect parents from burnout [14]. In many traditional African communities, parenting occurs within a collectivist environment of kin and community networks. It is consequently expected that every adult is responsible to play a role in educational terms even if the child is not a biological one. In this case education's role becomes social and collective. The responsibility passes from the family to the residents of the same village. The parental pressure is shared from the family to the community [15]. Similarly, the recent findings of a study in Poland demonstrate that the presence of social backing is a strong protective agent against parental burnout [16].

3 Methodology

3.1 Purpose of our study

The dominant goal of our research was to investigate the extent of burnout, depression, anxiety and stress experienced by parents with a child with disabilities in Greece. In particular, the negative emotional state is investigated, as well as the factors that may contribute to the occurrence of parental burnout, anxiety, stress and depression.

3.2 Main research question

The primary research question was whether the older parents have increased rates of parental burnout compared to younger parents, the older parents have higher levels of stress, anxiety and depression compared to the younger, the parents with more children have higher levels of parental burnout compared to parents who have a child, parents with more children have higher stages of stress, anxiety and depression compared to those who have a child and finally the correlation between the levels of parental burnout and stress, anxiety and depression.

3.3 Participants

The participants in the study are 50 parents of children with disabilities in Athens.

Table 1. Information on the demographic characteristics of the sample (n = 50)

	n	%
Educational level:		
High School	17	34,0
Higher Education/University	14	28,0
Technological Education	13	26,0
Postgraduate studies	6	12,0
Working status:		
Private employee	25	50,0
Freelancer	7	14,0
State employee	7	14,0
Unemployed	6	12,0
Other	2	4,0
Military	1	2,0
Medical staff	1	2,0
Scientific staff	1	2,0
Other children:		
Yes	30	60,0
No	20	40,0
Child Care:		
Mothers	48	96,0
Grandparents	1	2,0
Another person	1	2,0
Restriction of activities:		
Leisure time	32	64,0
Hobby/sports activities	11	22,0
Social/friendly contacts	7	14,0

3.4 Procedure

The data collection process took place in February 2022 and March 2022. Participants were informed about the research procedure and their consent was sought. They were also informed that there were no risks or inconveniences arising from participation in the research process and for the possibility to discontinue their participation at any time. They were also informed that their answers are completely confidential and fully anonymous. Then they were asked to answer once the Parental Burnout Assessment & Dass21 questionnaires as well as the demographic data form. The questionnaires were given to the participants through an application installed on their mobile phones. The application was able to open the electronic forms of the questionnaires. The aim was for participants to choose the answer that best describes how they personally feel, without taking time and making it clear to them that there is no right or wrong answer. The mean time to complete the 2 questionnaires and the demographic data form was 20 minutes.

1. The online form of PARENTAL BURNOUT ASSESSMENT (PBA) QUESTIONNAIRE

The online questionnaire consists of 23 closed-ended items rated on a 7-point Likert scale. Parental Burnout Assessment is not a clinical instrument and cannot diagnose parental burnout. If a person scores high on any of the 4 dimensions, referral to a specialist is required. The reliability of internal consistency (Cronbach's a) is > 0.85 [8]. In this study, the internal consistency indicators with Cronbach's alpha reliabilities were as follows: Exhaustion by parental role a = 0.93, contrast with previous parental self a = 0.88, feelings of being fed up as a parent a = 0.92 emotional distancing = 0.63 and total parental burnout a = 0.92.

2. The online form of DEPRESSION ANXIETY STRESS SCALE 21 (DASS 21)

The purpose of the questionnaire is to evaluate the negative situation (depression, anxiety, stress). The self-administered DASS 21 questionnaire is a set of three self-report scales, designed to measure the negative emotional dimension of depression, anxiety and stress [17]. It consists of 21 items. Each of the three DASS-21 scales contains 7 items, divided into subscales with similar content. The items are rated on a 4-point Likert scale where 0 = did not apply to me at all, 1 = applied to me to some degree, or some of the time, 2 = applied to me to a considerable degree or a good part of time, 3 = applied to me very much or most of the time.

DASS-21 is not a clinical instrument and cannot diagnose depression, anxiety or stress. It indicates whether any of these issues has a significant impact on one's life at the time being. If a person scores high on any of the scales, referral to a specialist is required.

The reliability of internal consistency (Cronbach's a) for the total scale is a = 0.93 and Standarized Item Alpha = 0.93. The reliability of internal consistency for the depression scale is a = 0.83, for the anxiety scale a = 0.81 and for the stress scale is a = 0.89. In the present study, the internal consistency indicators (Cronbach's a) for the stress, anxiety and depression scales were found as follows: stress a = 0.92, anxiety a = 0.92 and depression α = 0.88.

3.5 Statistical analysis

Statistical analysis was performed using SPSS Statistical Program 18 and included the estimation of the internal consistency of the questionnaires with the use of Cronbach's α coefficient, the descriptive statistics presenting median scores and range for each variable of the questionnaires as well as the investigation of relationships among the different subscales of the questionnaires through the Spearman Rho factor. In order to examine the first 2 research hypotheses regarding the differences between levels of parental burnout and anxiety, stress and depression levels in relation to age, Mann-Whitney U test was conducted since our data did not meet the criteria for normality. Accordingly, Mann-Whitney U test was applied to investigate the 3rd research hypothesis and the 4th research hypothesis.

4 Results

Table 2 presents the descriptive statistics (median and range) regarding the dimensions of parental burnout (Exhaustion in one's parental role / Contrast with the previous parental self / Feelings of being fed up with one's parental role / Emotional distancing from one's children) as well as regarding the stress, anxiety and depression levels of the sample (n = 50).

Table 2. Descriptive statistics (median and range) for the dimensions of parental burnout and levels of stress, anxiety and depression (n = 50)

	Median	**Range**
Total Parental Burnout	0,50	83
Exhaustion	29,50	31
Unlike the previous parent's self	17,00	30
Fatigued	15,00	22
Withdrawal	5,00	9
Stress	22,00	34
Anxiety	12,00	32
Depression	12,00	28

Furthermore, the rho correlation coefficient was applied to examine the correlations among the dimensions of parental burnout. Indeed, statistically significant positive correlations were found between the dimension of exhaustion in one's parental role and the dimension of the contrast with the previous parental self [Rho (50) = 0.35, p = 0.013], between the dimension of exhaustion in one's parental role and the dimension of feelings of being fed up with one's parental role [rho (50) = 0.74, p <0.0005], between the dimension of prostration in one's parental role and the dimension of withdrawal [rho (50) = 0.36, p = 0.010], between the dimension of the unlike with the previous parental self and the dimension of feelings of being fatigued with one's parental role [Rho (50) = 0.62, p <0.0005], between the dimension of the contrast with the previous parental self and the dimension of withdrawal [rho (50) = 0.63, p <0.0005] and between the dimension of feelings of being fatigued with one's parental role and the dimension of withdrawal [rho (50) = 0.57, p <0.0005] (Table 3).

Table 3. Correlation (Spearman Rho coefficient) among parental burnout dimensions (n = 50)

	Contrast	**Feelings of Being Fed Up**	**Emotional Distancing**
Exhaustion	0,35*	0,74**	0,36*
Contrast	–	0,62**	0,63**
Feelings of being fed up	–	–	0,57**

Notes: ** p< 0,01, * p< 0,05.

Similarly, the Spearman Rho correlation coefficient was applied to examine the correlations among levels of stress, anxiety and depression of the participants. In more detail, statistically significant positive correlations were found among levels of stress and anxiety of the sample [Rho (50) = 0.81, p <0.0005], among levels of stress and depression of the sample [Rho (50) = 0.81, P <0.0005] and among the levels of anxiety and depression of the sample, respectively [Rho (50) = 0.82, p <0.0005] (Table 4).

Table 4. Correlation (Spearman Rho coefficient) among levels of stress, anxiety and depression of participants (n = 50)

	Anxiety	**Depression**
Stress	0,81**	0,81**
Anxiety	–	0,82**

Notes: ** p< 0,01.

Hypotheses testing

As mentioned above, the violation of the assumptions of normality led us to conduct non parametric tests in order to examine our research hypotheses.

Therefore, Mann-Whitney U test was applied in order to examine our first hypothesis that younger parents (25–35 years, n = 25) will have reduced levels of parental burnout compared to older parents (36–50 years, n = 25). Specifically, with regard to overall levels of parental burnout, the analysis highlighted the important discrepancy between the two age groups with younger parents showing reduced levels of parental burnout (median = 46,00, range = 56) compared to older parents (median = 82.00, range = 32), U (N1 = 25, N2 = 25) = 1,000, p <0.00025.

Similarly, with regard to the dimension of exhaustion in one's parental role, a statistically significant difference was observed between the two age groups, with younger parents having reduced levels of exhaustion (median = 19.00, range = 11.00) compared to older parents (median = 40.00, range = 15), U (N1 = 25, N2 = 25) = 0.000, p <0.00025.

In addition, with regard to the dimension of the contrast with the previous parental self, the analysis, informed that there is a important variation, with younger parents having reduced levels of contrast with the previous parental self (median = 14.00, range = 30) compared to older parents (median = 17.00, range = 17), U (N1 = 25, N2 = 25) = 171,000, p = 0.003.

Similarly, regarding the dimension of being fed up with one's parental role, the analysis showed that there is a statistically considerable discrimination, with younger parents having reduced levels of feelings of being satisfied with one's parental role (median = 6.00, range = 15.00) compared to older parents (median = 19.00, range = 7), U (N1 = 25, N2 = 25) = 1,000, p <0.00025.

Continuing, with regard to the dimension of emotional distancing from one's children, a statistically significant difference was observed between the two age groups, with younger parents having reduced levels of emotional distancing from one's children (median = 4,00, range = 7) compared to older parents (median= 6.00, range = 8), U (N1 = 25, N2 = 25) = 157,000, p = 0.001 (Figure 1).

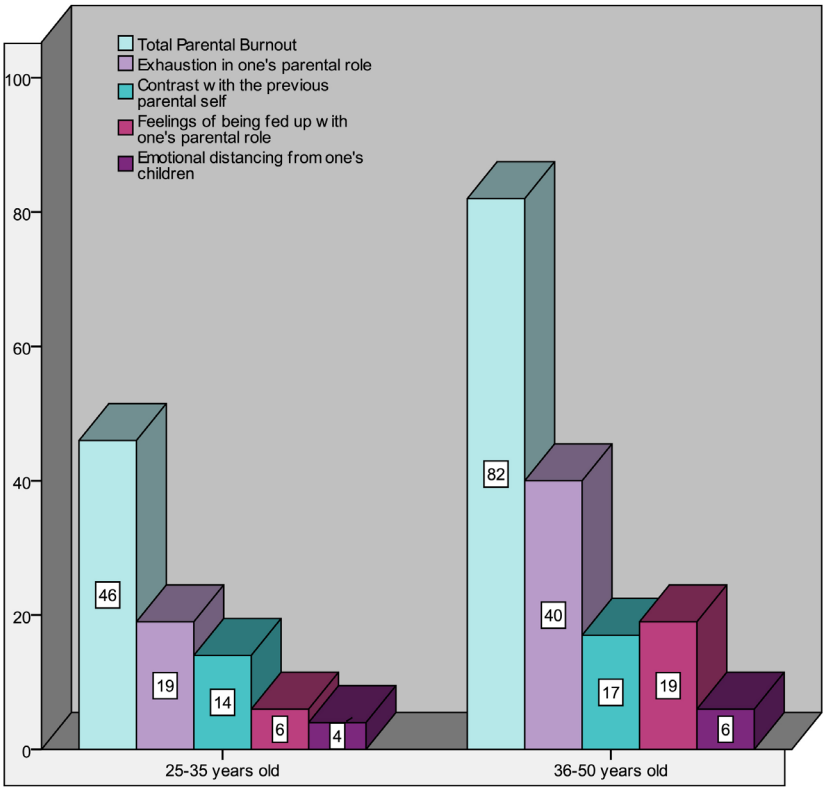

Fig. 1. Graph depicting differences in parental burnout levels with regard to age

Mann-Whitney U test was applied in order to examine our second research hypothesis that younger parents (25–35 years, n = 25) will have reduced levels of stress, anxiety, and depression compared to older parents (36–50 years, n = 25).

More specifically, regarding the dimension of stress, the analysis revealed statistically significant variation between the two age groups, with younger parents having reduced levels of stress (median = 12.00, range = 24.00) compared to older parents (median = 28.00, range = 16), U (N1 = 25, N2 = 25) = 12,000, p <0.00025.

Similarly, in terms of the dimension of anxiety, the analysis highlighted high differentiation values between the two age groups, with younger parents having reduced levels of anxiety (median = 2.00, range = 14.00) compared to older parents (median = 20.00, range = 22), U (N1 = 25, N2 = 25) = 4,500, p <0.00025. In addition, regarding the dimension of depression it was observed that there is a statistically significant difference between the two age groups, with younger parents having reduced levels of depression (median = 6.00, range = 22.00) compared to older parents (median = 16.00, range = 16), U (N1 = 25, N2 = 25) = 18,500, p <0.00025 (Figure 2).

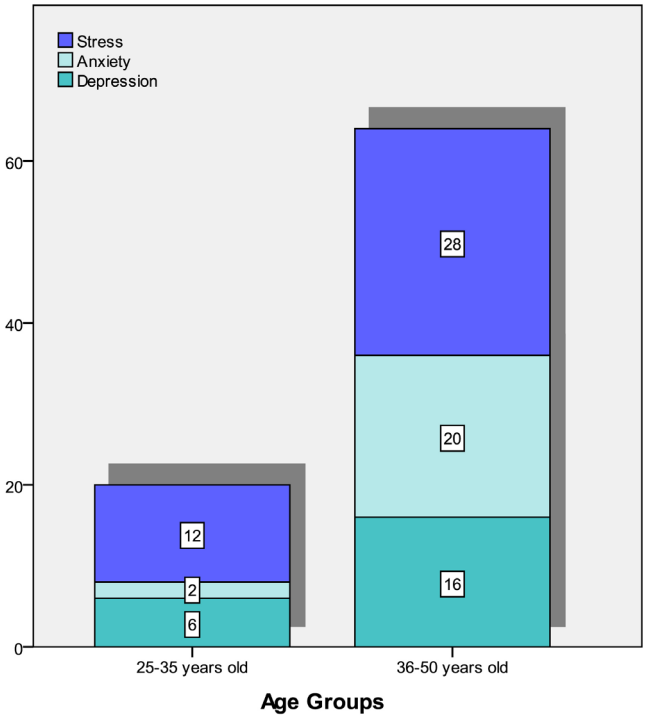

Fig. 2. Graph depicting differences in levels of stress, anxiety and depression with regard to age

Mann-Whitney U test for independent samples was applied in order to examine our third research hypothesis that parents with more children (n = 30) will have increased levels of parental burnout compared to parents who have only one child (n = 20).

Specifically, as for the overall levels of parental burnout, the analysis showed that the number of children is not an important factor (n1 = 30, n2 = 20) = 291,000, p = 0.429, also as for the dimension of exhaustion in one's parental role, U (N1 = 30, N2 = 20) = 267,500, p = 0.258.

In addition, as for the dimension of the contrast with the previous parental self, the analysis showed that there is no statistically significant difference between the two groups of parents in terms of the number of their children, U (N1 = 30, N2 = 20) = 249,500, p = 0.157.

Similarly, regarding the dimension of feelings of being fed up with one's parental role, the analysis showed that there is no statistically significant difference between the two groups of parents in terms of the number of their children, U (N1 = 30, N2 = 20) = 263,000, p = 0.231. In addition, regarding the dimension of emotional distancing from one's children, there was no statistically significant difference between the two groups of parents in terms of the number of their children, U (N1 = 30, N2 = 20) = 274,000, p = 0.300.

Subsequently, Mann-Whitney U test for independent samples was applied to examine our fourth research hypothesis that parents with more children (n = 30) will have increased levels of stress, anxiety and depression compared to parents who have only one child (n = 20).

Specifically, with regard to overall levels of stress, the analysis did not show the existence of a statistically significant difference between parents with more children (median = 25.00, range = 34.00) and parents with a child (median = 13.00, range = 28.00), U (N1 = 30, N2 = 20) = 261,500, p = 0.221.

On the contrary, with regard to the stress dimension, the analysis highlighted differentiation, with parents with more children (median = 16.00, range = 32.00) having increased levels of stress compared to parents who have a child (median = 8.00, range = 24.00), U (N1 = 25, N2 = 25) = 201,500, p = 0.025.

The dimension of depression, no notably results indicates parents with more children (median = 13.00, range = 28.00) and parents with a child (median = 10.00, range = 20.00), U (n1 = 30, n2 = 20) = 257,000, p = 0.195 (Figure 3).

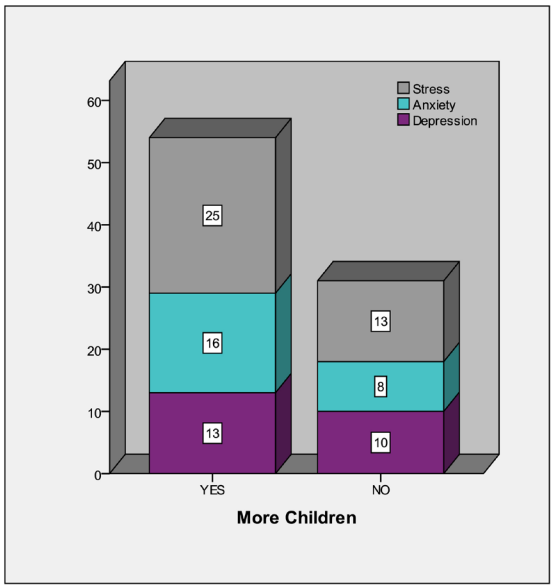

Fig. 3. Graph depicting differences regarding the number of children

Finally, the Spearman Rho correlation coefficient was applied to the entire sample in order to examine our fifth research hypothesis that parental burnout levels will be positively associated with levels of stress, anxiety and depression.

More specifically, statistically significant positive correlations were found between levels of total parental burnout and stress dimension [Rho (50) = 0.81, p <0.00025], between levels of total parental burnout and stress dimension [Rho (50) = 0.73, p <0.00025] and between the levels of total parental burnout and the dimension of depression [rho (50) = 0.79, p <0.00025].

Concerning the dimension of depletion, the analysis highlighted the existence of statistically significant positive correlations between participants' levels of exhaustion in one's parental role and stress levels [Rho (50) = 0.75, p <0.00025], between participants' levels of exhaustion in one's parental role and anxiety levels [Rho (50) = 0.73, p <0.00025] and between participants' levels of exhaustion in one's parental role of participants and depression levels, respectively [Rho (50) = 0.70, p <0.00025].

Similarly, regarding the dimension of the contrast with the previous parental self, statistically significant positive correlations occurred between the levels of these factor and the dimension of stress [Rho (50) = 0.46, p <0.00025], between the levels of conflict with the previous feelings and the dimension of anxiety [rho (50) = 0.35, p = 0.003].

In addition, statistically significant positive correlations were observed between participants' levels of feeling fed up with one's parental role and the dimension of stress [Rho (50) = 0.78, p <0.00025], between participants' levels of feeling fed up with one's parental role and the dimension of anxiety [rho (50) = 0.76, p <0.00025] and between participants' levels of feeling fed up with one's parental role and the dimension of depression, respectively [rho (50) = 0.81, p <0.00025].

Also, regarding the dimension of withdrawal, the analysis highlighted the existence of statistically significant positive correlations between the levels of emotional distancing of the sample and the dimension of stress [Rho (50) = 0.55, p <0.00025], between levels of emotional distancing of the sample and the dimension of anxiety [rho (50) = 0.30, p = 0.008] and between the levels of emotional distancing of the sample and the dimension of depression, respectively [rho (50) = 0.54, p <0.00025] (Table 5).

Table 5. Correlation (Spearman Rho correlation coefficient) between dimensions of parental burnout and levels of stress, anxiety and depression (n = 50)

	Stress	**Anxiety**	**Depression**
Total parental burnout	0,81**	0,73**	0,79**
Exhaustion	0,75**	0,73**	0,70**
Unlike with the previous parental self	0,46**	0,35**	0,50**
Fatigued	0,78**	0,76**	0,81**
Withdrawal	0,55**	0,30*	0,54**

Notes: ** p< 0,01, * p< 0,05.

5 Discussion

The integration of digital technologies in the special education field always has successful results in recording and facilitating every process through mobile phones [37–46], ICT apps [47–79], AI & STEM [80–91], and games [92–97]. Furthermore, the combination of ICT and theories of metacognition, mindfulness, meditation and emotional intelligence cultivation [98–121] as well as environmental factors and nutrition [33–36], develop positive educational and parenting practices.

Despite the above benefits there are the issues of burnout. The survey on parental burnout is still in beginning, but researchers have demonstrated reliable measured [1,8] that its prevalence requires further investigation [6,8], that it is related to sociodemographic, personal, parental and marital factors [7] and that it has negative consequences for the child, such as neglect and violence [32] but also for the parent, such as thoughts of escape and suicidal ideations [7].

The present study aims to explore the level of burnout, depression, anxiety and stress experienced by parents with a child with a disability in Greece, as well as the factors that may contribute to the emergence of parental burnout, anxiety, stress and depression. The results show that mothers are the ones who, in a percentage of 96.0%, take care of the child, which is not surprising as the mother usually has the burden of caring for the child with disability [18,19,20,21], an element that is also reflected in the present study.

A very interesting conclusion from the research concerns the research hypothesis that younger parents (25–35 years) have reduced levels of parental burnout compared to older parents (36–50 years). Indeed, the statistical analysis of the data shows that, in terms of overall levels of parental burnout and its individual dimensions, younger parents have reduced levels of parental burnout compared to older parents. Similarly, the results of this research study confirm the second research hypothesis that younger parents (25–35 years) have reduced levels of stress, anxiety and depression compared to older parents (36–50 years).

Consequently, the age of parents was positively associated with parental burnout levels, stress, 1,7anxiety, depression, with parents aged 36 to 50 showing higher rates. These findings confirm other studies, according to which older parents feel severe psychological distress, anxiety and stress [22,23]. One reason that probably contributes to this is parents' anxiety about what will happen to the child with a disability when they will no longer be able to care for him/her. The parents who participated in the study have children from 1 to 6 years old. It is believed that the care of preschoolers with disabilities, contributes to the emergence of increased levels of mental distress [10,8], which is also illustrated by the findings of the present study. The fact that the majority of parents interviewed are working also probably contributes to this. At the same time, based on the study findings, participants' free time, hobbies and sporting activities, as well as social and friendly contacts, have been limited.

Also, 60% of participants stated that they have other children, while 10.0% reported that their other child has a chronic health or disability issue. According to bibliographical references, the existence of more children is a risk factor for both emotional distancing and for loss of parental achievement [8,24] However, our research hypotheses that parents with more children have increased levels of parental burnout, stress and depression compared to parents who have only one child have not been confirmed. The analysis highlighted the existence of a difference between the two groups, only in terms of stress, with parents with more children having increased levels of stress compared to parents who have a child.

Concerning the correlation between levels of parental burnout and stress, anxiety and depression, findings have shown statistically significant positive correlations between the levels of parental burnout and levels of stress, anxiety and depression of participants. The aforementioned results coincide with researchers' findings that

parental burnout is a distinct syndrome and differs from depression, professional burnout, stress and anxiety of parents, but is directly related to them [25,9,26,27,28,29]. This correlation may be due to the fact that parents are so burdened by their parental role, taking care of the child with disability, that they often neglect their own physical and mental health. They experience anxiety with sadness, anger, guilt, to a point that the mere thinking of what to do for or with children seems unbearable, or are no longer the parents who were or wanted to be.

The results of this study confirm the prevailing view of the scientific community that developmental disabilities often lead to high rates of parental burnout, anxiety, stress, and depression. Indeed, it appears that the participants in the study have a tendency for parental burnout. Regarding the individual dimensions of parental burnout, parents seem to experience mainly exhaustion. Parents feel that being a parent requires total commitment. They feel burdened by the parenting role due to their extensive responsibilities and that they have reached the end of their endurance.

Additional reasons that can justify the burden that parents feel are the lack of support both from the wider family network and from the services, the disruption of relationships among family members and the increased obligations due to child care of children. Parents with children with disabilities need support and assistance, both by other family members [30] and the wider social context.

Parents in socially isolated societies are more prone to parental burnout than those coming from more solidarity societies [11]. Social support and government subvention are the most powerful protective factors against parental burnout [31,32] and the burden of responsibility for raising a child should not be shouldered only by the parents but there should be a circle of relatives and professionals to support the parents and the child.

It is especially important to identify parental resources through a systematic assessment of parents' needs. This will be an important step in prevention but also in guiding parents towards appropriate supportive interventions and services. Parent support programs should not only focus on the needs of a child with disabilities but they should also strengthen parents and encourage them to take care of themselves as this will benefit not only themselves but also their children. Proper information is essential so that parental burnout ceases to be a taboo subject and parents are empowered to seek the help they often need.

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Early Bacterial Detection in Bloodstream Infection using Deep Transfer Learning Algorithm

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Abstract—An infection caused by bacteria can lead to severe complications affecting bloodstream disease. At present, blood cultures are used to identify bacteria. However, blood culture is a time-consuming and labor-intensive method of diagnosing disease. The effect of delayed early diagnosis is that it influences the mortality risk. Thus, it is urgent to develop an initial prediction model to identify patients with bloodstream infections. This paper focused on classifying the bacteria using a deep-learning approach. Besides, deep learning techniques can enhance the bacterial classification process more effectively. The transfer learning-based convolutional neural network technique is used to develop our model. In addition, we compared the proposed model with another model used to find the best results. Compared to other models, the proposed model achieved an evaluation score with high accuracy of 98.62%. Medical decision-making may benefit from the proposed approach.

Keywords—transfer learning, bacterial, bloodstream disease, convolutional neural network

1 Introduction

Once bacteria enter the body, reproduce, and stimulate the immune system, they create infections. A bacterial infection can cause bloodstream problems. A bloodstream infection (BSI) is diagnosed when blood cultures are positive and systemic symptoms are present. This infection could be secondary to a previously identified cause, or it could be primary and have no explanation. Among all causes of death, BSIs rank very high. [1]. BSI patients have a significant morbidity rate worldwide, with 15–30% fatality rates [2].

In order to effectively treat a disease that is circulating through the body, it must first be diagnosed. Bloodstream infections (BSIs) are diagnosed whenever a blood culture or cultures are positive in a patient exhibiting systemic signs of infection (fever, hypothermia, chills, hypotension, oliguria, or elevated lactate levels) [3]. Blood culture is a time-consuming, complicated method for identifying illnesses [4]. In addition, delays in antimicrobial medication delivery may increase the death risk [5]. Many attempts have been made to develop accurate BSI biomarkers. Early diagnosis of BSI is crucial. However, most laboratory-based methods fail [6].

Computerized techniques, such as computer-aided treatment regimens and artificial intelligence, have been developed to assist doctors in detecting bloodstream infections and diseases [7]. Computerized infection monitoring can quickly diagnose health issues, reduce risk, and detect infections [8][9]. Deep learning is a subset of machine learning that consists of many artificial neural networks that are linked sequentially. Kant *et al*. proposed using a cascading technique and a fully-convoluted, five-layer neural network architecture. They reached an 83.78% sensitivity score [10]. Kim *et al*. employed a CNN model based on the pre-trained framework to categorize bacterial images on ODT with 85% accuracy [11]. Hongda *et al*. classified pathogenic bacteria in food, water, and body fluid through time-lapse imaging. They use deep learning approaches for the detection of agar plate bacteria. The approach could identify 80% of positive colonies [12]. Brodzicki *et al*. used pre-trained DenseNet 201 to evaluate the CDI of fluorescence images, achieving an accuracy of 93.5% [13]. This study aimed to present a deep transfer learning algorithm that can predict and classify bacteria contributing to bloodstream infection while reducing misclassification or poor decision-making.

2 Background and material overview

2.1 Deep transfer learning

Deep transfer learning (DTL) teaches a machine to solve one problem and apply that knowledge to others [14], [15]. Before development, the network is "trained" on the proper data set. Then, it's applied to the intended dataset by another process. DTL uses a pre-trained model to classify new datasets, and neither data training is required. A pre-trained model freezes remaining layer weights, add new fully connected layers and retrain smaller images. This technique is used with similar, small data. Retrain (fine-tuning) the network model with a new target without overfitting unless the second target contains the exact fit and features as the first. DTL increases efficiency and unlabeled data. Fine-tuning or retraining these architectures for medical data is also a successful approach [16]–[18].

2.2 Proposed method

This research performed fine-tuning on four different CNN models: AlexNet [19], VGG16 [20], GoogleNet [21], and Inception-ResNet-v2 [22]. This paper uses a benchmarked approach that uses a customized convolutional neural network framework. The process is mapped out in the diagram here (Figure 1). The final fully connected layers

in each of the four CNN models involved have been reduced from their original number to just six classes. In addition, the activation function known as softmax can be found buried deep within the last dense layer. This function makes an important contribution to the process of predicting the category of the data that is provided. We evaluate the classification proceeds using a confusion matrix such as accuracy, sensitivity, PPV, and F1 Score.

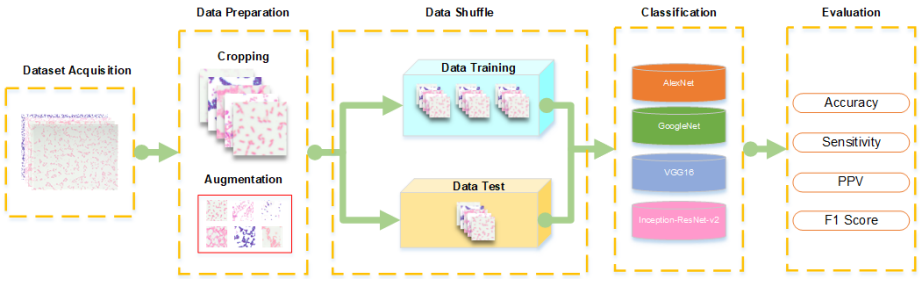

Fig. 1. The proposed method schemes

2.3 Dataset acquisition

The six bacteria species image was built in Parasitology Laboratory with conducting magnified under the fluorescent microscope in 40x zoom. We found positive and negative bacilli, cocci, and diplococci in the samples. The microbiologists provided labeling of the bacterial species according to their class while they were collecting the data. In the database, there are 954 images generated from slide samples. The several bacterial names are *Burkholderia pseudomallei sp*. (BP) which is a gram-negative bacterium, *Hemophilus influenzae sp.* (HI) is gram-negative coccobacilli, *Klebsiella pneumoniae sp.* (KP) is a gram-negative bacterium, and *Pseudomonas aeruginosa sp.* (PA) is a gram-negative rod-shaped bacterium, *Streptococcus pneumoniae sp.* (SP) is a gram-positive bacterium, then *Staphylococcus aureus sp.* (SA) is a gram-positive bacterium. Figure 2 depicts bacteria species images.

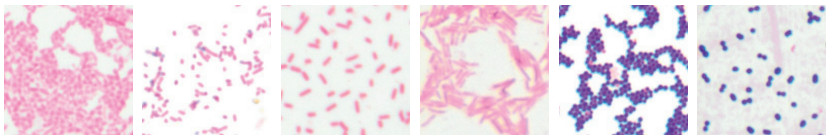

Fig. 2. Sample of the bacterial species: (a) BP, (b) HI, (c) KP, (d) PA, (e) SA, (f) SP

2.4 Data preparation and data shuffle

DL models with low quantities of data can obtain poor performance results. Most of the performance results of the CNN model are influenced by the availability and balance of the dataset [23]. Unless the data set is too limited or too slight, it might generate biased results toward the significant number among each class [24]. On the

other hand, fewer datasets could happen the over-fitting problem, but the augmentation approaches would reduce it during the training process [25]. Therefore, this study proposed augmentation techniques on all image datasets, such as translation, rotation, scaling, inversion, and reflection methods. Before the augmentation is performed, we cropped the data set to reduce the image size for image input. These approaches are beneficial to improve the model accuracy performance. Furthermore, all image datasets are prepared for the model proposed by split into two data stored: 70% of the data will be used for the training model, then 30% will be used for testing the model.

2.5 Convolutional neural network

A convolutional neural network is a powerful technique for machine learning that stems from deep learning. CNN models classify the information using features extracted from the labeled training data [26]. A CNN typically consists of blocks of convolution and subsampling layers, followed by one or more fully connected layers, and finally, an output layer [26].

A convolution is described by equation (1). i denotes the input size, k the filter size, s the number of steps, p the padding process, and o the output size.

$$o = ((i - k) + 2p)/s + 1 \tag{1}$$

By applying filters to the input data, we can increase the network's depth and train it to produce more precise predictions [27]. The convolution process is represented by equation (2). S stands for output after the convolution process, K stands for the kernel, and I stands for the input image.

$$s(i, j) = (I * K)(i, j) = \sum_m \sum_n I(m, n)K(i - m, j - n) \tag{2}$$

In addition, the cross-entropy operation can be performed with equation (3).

$$s(i, j) = (I * K)(i, j) = \sum_m \sum_n (i + m, j + n)K(m, n) \tag{3}$$

$$Y = \frac{W - F}{s} + 1 \tag{4}$$

Then, equation (4) illustrates pooling. With The new image's size, in Y. W stands for the image's width. S for the number of steps, and F for the filter size. CNN architectures are increasingly incorporating activation and dropout layers. Popular activation functions include Tanh, Sigmoid, and Relu [28]. Fully Connected is a popular CNN layer. Feature maps feed the layer. Those are used for classification and transforming multidimensional feature maps into a single dimension for the classifier.

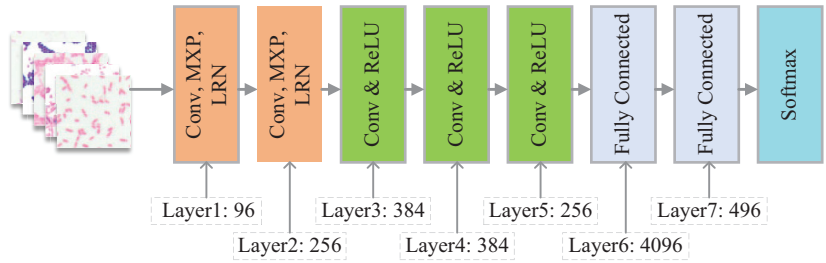

Fig. 3. The AlexNet model

AlexNet model. After a long period of inertia, deep learning has entered a new era [19]. Deep learning models are popular after Alexnet's success. The network training used around a million images and could differentiate 1,000 items. Then it has a larger LeNet-5-like architecture. Five convolutional and three fully linked layers. Using ReLU after convolutional and FC layers helped train their model faster than tanh networks. After each LRN layer is a max-pooling and fifth convolutional layer. Figure 3 illustrates AlexNet.

VGG16 model. VGG16 model has a unique feature: rather than having many hyper-parameters [20], the developers focused on convolution layers of 3x3 filters with a stride 1 and padding and max pool layers of 2x2 filters with a stride 2. The architecture consistently uses convolution and max pool layers. After two fully connected FCs, the output is a softmax. VGG16 is an abbreviation for its 16 weighted layers and 138 million parameters. VGG16 is depicted in Figure 4.

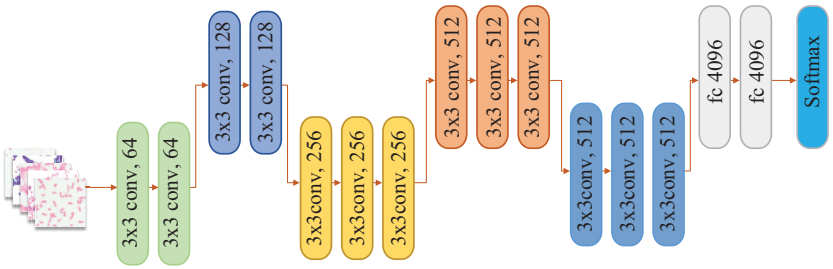

Fig. 4. The VGG16 model

GoogleNet model. Christian Szegedy of Google proposed GoogleNet to reduce CNN's computational complexity [21]. Different kernel sizes were used to create "Inception Layers" with variable receptive fields. These receptive fields captured sparse correlation patterns in the new feature map stack. They did this by employing parallel filters known as the inception module, which allowed them to increase the number of units in each layer. Figure 5 is an illustration of the GoogleNet model.

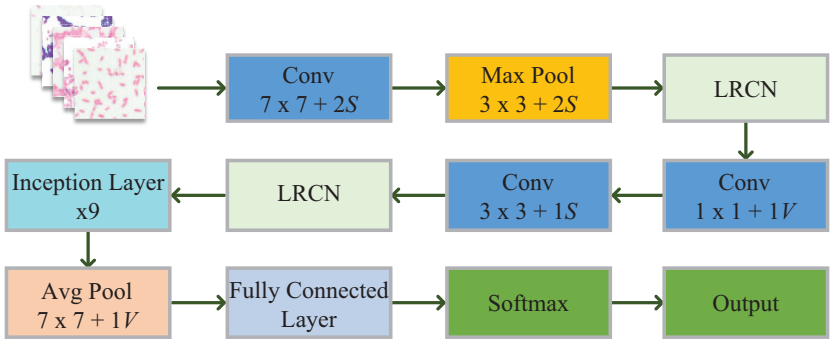

Fig. 5. The GoogleNet model

Inception-ResNet-v2 model. According to the Inception network structure [22], multiple convolution kernels of different sizes can improve the network's adaptability and extract more abundant features at different scales. Simultaneously, by using the NIN model [29], the Inception network structure can significantly reduce model parameters, allowing the network to reduce the number of convolution kernels as much as possible without losing model feature representation, thereby reducing model complexity. Inception-ResNet-v2 architecture is as follows in Figure 6.

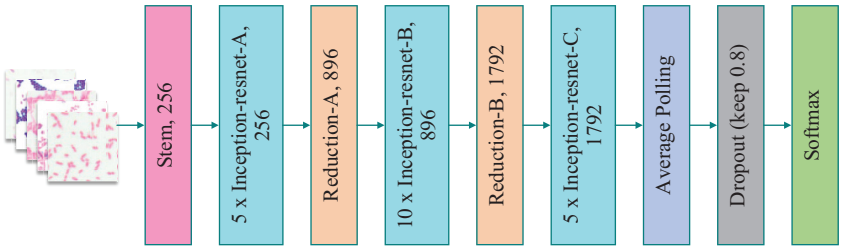

Fig. 6. The Inception-ResNet-v2 model

2.6 Evaluation

It is common practice in artificial intelligence to use the confusion matrix to measure the accuracy of predictions. This matrix counts the number of instances in which an organism was correctly identified as true bacteria (TP), correctly identified as false bacteria (TN), incorrectly correctly identified as false bacteria (FP), and incorrectly identified as true bacteria (FN). This study visualized the accuracy, sensitivity, PPV, and F1 Score as follows: Equations 5–8.

$$\text{Accuracy} = \frac{(TP + TN)}{(TN + FP + TP + FN)} \tag{5}$$

$$\text{Sensitivity} = \frac{TP}{(TP + TN)} \tag{6}$$

$$\text{PPV} = \frac{TP}{(TP + FP)} \tag{7}$$

$$F1\ Score \frac{2 * TP}{(2 * TP + FN + TN)} \tag{8}$$

3 Simulation results and discussion

3.1 Simulation and training

It is possible to enhance computation time while data training by organizing the hyper-parameter. A hyper-parameter is mainly increasing the accuracy performance. This model was set up with an epoch of 15, a learning rate of $10^{e\text{-}5}$, and a batch size of 32. While the optimizer is Adam optimization. In addition, the simulation was generated using Matlab, which operated on Windows 10. The simulation process was supported by using the Graphics Processing Unit (GPU) of the NVIDIA series with 32 GB of RAM. Figures 7–10 show the accuracy and validation loss during training.

Figure 7 shows the AlexNet model during the training. The training cycle was completed iteration (144) per epoch (11996). Figure 8 illustrates the GoogleNet model that throughout the training dataset, the training cycle was completed iteration (168), iteration per epoch (984). Figure 9 depicts the VGG16 model during training. The training cycle was completed iteration (242) per epoch (984). Figure 10 displays our proposed model using Inception-ResNet-v2 that during the training dataset, the training cycle was completed iteration (327), iteration per epoch (1988). On the other hand, the amount of necessary iteration is proportionate to the outcomes that were acquired, which shows that the process was successful.

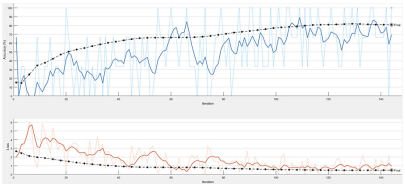

Fig. 7. AlexNet training graph

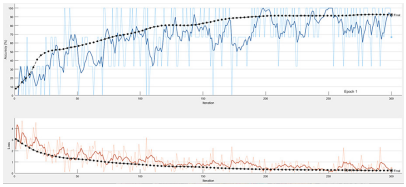

Fig. 8. GoogleNet training graph

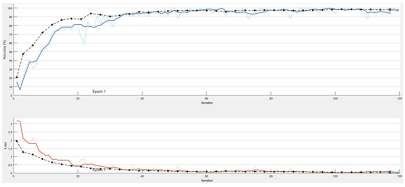

Fig. 9. VGG16 training graph

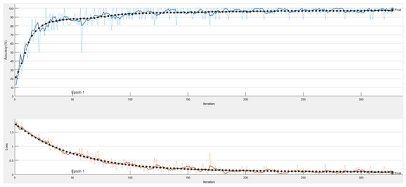

Fig. 10. Inception-ResNet-v2 training graph

3.2 Result and discussion

This study proposed the classification of bacteria microorganism which is infected the human bloodstream. Infection of the bloodstream, also known as BSI, is linked to significant morbidity and mortality [29]. There are six genera of bacteria involved. Four CNN models of AlexNet, VGG16, GoogleNet, and Inception-ResNet-v2 (proposed model) are utilized to predict each bacteria class.

Table 1. Evaluation score achieved with various model

Framework	Class	Accuracy	Sensitivity	PPV	F1 Score
AlexNet	BP	53.65%	80.50%	83.10%	0.8178
	HI	65.51%	94.80%	98.30%	0.9554
	KP	50.50%	75.70%	89.50%	0.8202
	PA	62.12%	93.20%	79.20%	0.8563
	SA	61.93%	92.20%	99.60%	0.9613
	SP	61.51%	99.80%	96.10%	0.93.37
	Average	59.20%	89.37%	90.97%	0.8908
GoogleNet	BP	93.12%	93.20%	95.00%	0.9410
	HI	99.25%	99.20%	99.10%	0.9915
	KP	95.90%	95.80%	91.50%	0.9360
	PA	94.80%	94.80%	97.00%	0.9590
	SA	97.90%	97.90%	99.90%	0.9890
	SP	99.94%	99.90%	99.20%	0.9487
	Average	96.82%	96.80%	96.95%	0.9609
VGG16	BP	98.03%	99.10%	93.00%	0.9595
	HI	99.75%	99.00%	97.10%	0.9804
	KP	99.06%	92.10%	99.70%	0.9575
	PA	95.74%	96.40%	99.70%	0.9802
	SA	94.92%	99.10%	99.90%	0.9950
	SP	99.96%	100%	99.40%	0.9970
	Average	97.91%	97.62%	98.13%	0.9783
Inception-ResNet-v2	BP	99.57%	99.60%	95.10%	0.9534
	HI	98.20%	98.20%	99.90%	0.9904
	KP	96.73%	96.70%	99.70%	0.9818
	PA	98.95%	99.00%	99.50%	0.9925
	SA	99.62%	99.70%	97.80%	0.9874
	SP	98.67%	98.70%	99.80%	0.9925
	Average	98.62%	98.65%	98.63%	0.9830

Based on Table 1, the best scores for accuracy, sensitivity, PPV, and F1 Score were: HI (65.51% for accuracy), 99.80% for sensitivity (SP), 99.60% for PPV, and 0.9613 for F1 Score (SA). This performance was made possible by the AlexNet model that

had already been trained. On the other hand, GoogleNet achieved the best accuracy, sensitivity, PPV, and F1 Scores as follows: 99.94% of accuracy and 99.90% of sensitivity (SP), 99.90% of PPV (SA), then 0.9915 of F1 Score (HI). Furthermore, VGG16 generated the best accuracy, sensitivity, PPV, and F1 Scores as follows: 99.96% of accuracy, 100% of sensitivity, and 0.9970 of F1 Score (SP), then 99.90% of PPV (SA). For our proposed model by Inception-ResNet-v2, which obtained the best accuracy, sensitivity, PPV, and F1 Scores were as follows: 99.62% of accuracy, 99.70% of sensitivity (SA), 99.90% of PPV (HI), 0.9925 of F1 Score for (PA) and (SP).

In addition, Figure 11 depicts a comparison of the average performance scores of the various models. As a result, which is described using the proposed model, where the average score of the evaluation matrix reaches the highest average score of 98.62% of accuracy, 98.65% of sensitivity, 98.63% of PPV, and 0.9830 F1 Score compared with other models. Besides, the AlexNet model achieves a lower accuracy, with an accuracy of 59.20%. The VGG16 model outperforms the GoogleNet model across the board.

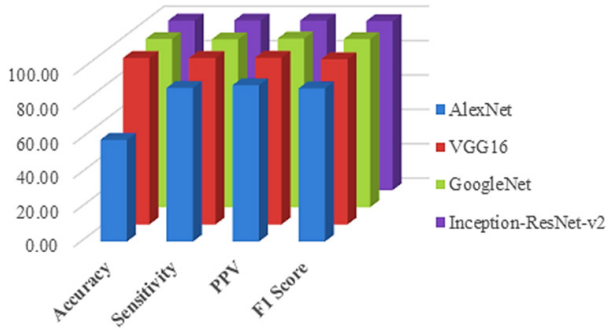

Fig. 11. Comparison of the average performance scores of various models

As mentioned later, artificial intelligence technologies, including deep learning and other methods based on imaging data, have been used to forecast microorganism images. In 2018, Smith *et al*. employed a deep learning-based InceptionV3 model to classify the Gram smear images and reported an accuracy of 94.9% [30]. Furthermore, Kuok *et al*. in 2019 developed automated detection for bacterial images using Faster-CNN and then obtained an accuracy of 86% [31]. Tamiev *et al*., in 2020, created a 4-layer CNN and achieved an accuracy classification score of 86% [32]. On the other hand, Wang *et al*. implemented NuggenNet, which was used to recognize and categorize the bacteria seen in microscope images. In 2022, they achieved a sensitivity of 82% while maintaining a 75% accuracy rate. [33]. Regarding ideas, our outcomes demonstrate that the proposed model, when compared to other models, is acceptable at classifying bacteria on microscope images. The high accuracy achieved by Inception-ResNet-v2 was 98.62%.

4 Conclusion

This study proposed bacteria classification for early prediction of various genera utilized to assist paramedics in decision-making. Computer-aided detection (CAD) that involves artificial intelligence techniques (machine learning, deep learning) can improve diagnosis. For those, this paper suggested the deep learning approach with a deep transfer learning algorithm that classified the characteristics of bacteria using an evaluation matrix (accuracy, sensitivity, PPV, and F1 Score). We compared the proposed CNN model (Inception-ResNet-V2) with AlexNet, VGG16, and GoogleNet, which several researchers have implemented into the medical imaging dataset. The final result, which used deep transfer learning, had the best performance using our proposed framework, with a reach accuracy of 98.62%, a sensitivity of 98.65%, a PPV of 98.63%, and an F1 Score of 0.9830. This technique could be an expert support system in medical technology, particularly in detecting rapid bacteria.

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An Image Feature Extraction to Generate a Key for Encryption in Cyber Security Medical Environments

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Abstract—Cyber security is a term utilized for describing a collection of technologies, procedures, and practices that try protecting an online environment of a user or an organization. For medical images among most important and delicate data kinds in computer systems, the medical reasons require that all patient data, including images, be encrypted before being transferred over computer networks by healthcare companies. This paper presents a new direction of the encryption method research by encrypting the image based on the domain of the feature extracted to generate a key for the encryption process. The encryption process is started by applying edges detection. After dividing the bits of the edge image into (3×3) windows, the diffusions on bits are applied to create a key used for encrypting the edge image. Four randomness tests are passed through NIST randomness tests to ensure whether the generated key is accepted as true. This process is reversible in the state of decryption to retrieve the original image. The encryption image that will be gained can be used in any cyber security field such as healthcare organization. The comparative experiments prove that the proposed algorithm improves the encryption efficiency has a good security performance, and the encryption algorithm has a higher information entropy 7.42 as well as a lower correlation coefficient 0.653.

Keywords—cyber security, medical image encryption, feature extraction, diffusion, randomness, key generation

1 Introduction

Businesses utilize the cyber security as well as the physical security measures for preventing unauthorized access to the data centers and the else electronic systems. One aspect of cyber security that this protection is aimed at defending is the privacy, stability, and availability of digital information. The demand for instantaneous, high-quality content security for digital medical pictures is rising with the proliferation of computing and networking technologies that make it feasible to distribute such images [1, 2].

The widespread availability of digital devices has facilitated the easy distribution of digital photographs to anybody. Conventional encryption approaches are ineffective in directly protecting e-health data due to size, redundancy, and capacity constraints, particularly when the patient data is provided via open channels [3]. The digital picture is one of the most important techniques of conveying vast quantities of information, however to transfer this format safely, some cryptographic approach is required. Multiple methods of encryption have emerged in recent years, greatly enhancing the safety of online picture sharing. Images have a high pixel high redundancy and correlation, but the traditional encryption techniques, like International Data Encryption Algorithm (IDEA), Data Encryption Standard (DES), Advanced Encryption Standard (AES), and Rivest Shamir Adleman (RSA) being created for text information. Thus, the other lightweight encryption technique has become one of the most prominent picture encryption method [4, 5] and is frequently employed in cryptosystems. Some photos are very sensitive, some images include secret data, and some images are delivered through insecure transmission channels, therefore protecting them from any assault is necessary [6]. Visual cryptography is one technique to ensure the image data security. By using visual cryptography, images may be encrypted in such a manner that they cannot be decoded during the transmission. In order to prevent the frequency attacks, most lightweight cryptography relies on the notion of diffusion/confusion of the image bits [7, 8]. There are two potential dangers for picture data: First, the sensitive information might be leaked from the image itself. Second, the picture data must be protected during the transmission since it may be stolen and altered before being sent across a network [9]. The efficacy of an encryption method is dependent on the quality of its key. On the other hand, the expanded key presents several challenges, such as a higher risk of forgetting and a higher barrier to storage. The external nature of the key also introduces a security risk into the encryption algorithm [5, 10, 11], and the present research is centred on the encrypting patient x-ray images, so they could be securely transmitted over a network. To do this, the diffusion principle has been followed which is applied to the pixels of the original images to generate the secret key, tested its randomness, and then used it to encrypt the image.

2 Related works

Now more than ever, the information security must be bolstered due to the prevalence of defensive data being kept and communicated digitally across insecure channels. The visual component of data is crucial. The need to secure the images from prying eyes has led to several adaptations of various encryption methods by researchers. As an example, [12] presented a technique for a two-dimensional chaotic map and two secrets, both of which are relevant to the many different kinds of studies now being conducted on substitutions, permutations, chaotic maps, spatial domains, diffusion, etc. Picture encryption keys are generated by first slicing the image into four sections, then encrypting each section individually n times, then reversing the keys for each section, and finally repeating the process n times. As introduced by Al-Haj A. et al. in [13],

the watermark picture may be embedded in the source image by using the Histogram Shifting RDH technique in the spatial domain. A partially encrypted picture was produced. Pixel permutation was used to produce the key, and another spatial domain watermark picture was utilized to encrypt the key using the RDH Histogram shifting technique. Finally, the watermarked image and the encrypted watermarked image of 8-bit planes were merged to form 16-bit planes. By treating the generation of keys as a 5D conservative hyper-chaotic system, Zhou M., et al. [14] created a novel, safe technique of encrypting images. When using a diffusion mechanism that relies on both plaintext and ciphertext, from encrypting the 1st. plaintext pixel block to encrypting the final pixel block and then modernizing the 1st. cypher text block, the chaotic system utilized for generating the pseudorandom orders must remain unchanged, and the important encryption model's streams must be random. In [15], the Josephus sequence, two hyper chaotic systems (1-D and 6-D), LFSR generator, and SHA-512 hash function and were all employed together. Three efficient scrambling operations were utilized for permuting the columns and rows locations. With studies, like differential attacks and fault propagation, their method is able to achieve a great performance and a high resistance to a wide variety of security threats. When encrypting a picture, a special key is utilized, and both the encryption and decryption steps from [16] must be taken into account. For this reason, the idea of partial picture encryption has been investigated. For the original picture to be recovered after encryption, the receiving end must have access to the same key. In contrast, the approach presented by Zhou B. et al. in [6] uses a fractal diagram to encrypt pictures by transforming them into a series of random patterns whose shapes are determined by the parameters used in the pattern's production. Using the inverse technique, it may recover the original picture using these keys by analyzing the form's shape pattern. Fractal images of various forms may be generated by performing this transformation, with the original images' security assured. According to the findings, the proposed system is both efficient and secure in its execution, requiring little time for calculations. An example of an elliptic curve cryptosystem was provided by the method of picture encryption described in [17]. An elliptic curve is shared by the two communicating parties. The sender first aggregates the pixel data and transforms them to large integers, and then the sender encrypts the big integers using ECC and the chaotic system, resulting in shorter encryption times. In the end, the encrypted large numbers are used to create the encrypted picture. While the suggested approach provides more security and greater accuracy, the encrypted message is larger in size. To manage the encrypted data transfer over open networks, in [8], a visual cryptography system, whose central principle is the encryption of an image that disperses a secret across m different image shares, is found in this work. This method makes it difficult for hackers to recover the original picture data. There is also a need to use the effective encryption technique to protect the original image's privacy and security. Using this theory, a novel method of picture encryption and decryption that use the diffusion technique and a mix of chaotic maps is created in the current study.

3 Image encryption

The most advanced encryption technology [1] will ensure that the businesses are properly secured from cyber threats. Most security systems use encryption because it is one of the most effective means of keeping sensitive information safe. The subtleties of biometrics vary from one person to the next, making it difficult to construct a security system that relies on them; however, when the biometric system is used, it is important to be aware of the risks involved, such as what happens if the reference template is exposed by a meddler [18, 19]. This issue is addressed by cryptography, the encrypted data security is reliant upon (2) factors: The cryptographic algorithm robustness and the key secrecy and how a secret key method being distributed [11, 20]. This categorises the crypto-systems as either private-type (symmetric) key or public-type (asymmetric) key. When employing a public key to encrypt plaintext, the resulting ciphertext must be decrypted using a corresponding private key. Private-key cryptography uses a single key that is shared by the sender / receiver for both encryption and decryption [5].

When it comes to information security, the studies focusing on protecting the digital images are a promising new area. The existing picture encryption algorithms distort the original image into a meaningless random noise signal, making it more vulnerable to attack [6]. In order to ensure the safety of data in interactive media prior to transmission over an unsecured channel, numerous picture encryption algorithms have been developed recently. In the realm of picture encryption, the starting value of pseudo randomness, chaos, ergodicity, and parameters, in addition to the process technique that is utilised, are very sensitive [17, 21].

4 Features extraction

Processing that characterises' borders, a crucial and fundamental characteristic in image processing is called "Edge Detection and Feature-Extraction," and it is essential to the motion identification process. By pinpointing abrupt changes in pixel values, the edge detection helps define the image's areas, lowers the data and filters out the noise without sacrificing the image's essential structural qualities. With most photos degraded by noise or certain data possession devices, lighting circumstances, etc., an enhanced image is necessary for understanding. Most edge detection techniques start with the premise that the edges are detectable anywhere there is a break in the picture. Using this premise, one can derive the derivative of the image's intensity value and find the spots where the derivative is maximal, pinpointing the edges [22–30].

5 Sobel edge detectors

Using edge detection, one may decrease the amount of data in a picture while still retaining the crucial features. The proposed method uses Sobel edge detection, which aims to maximise the accuracy with respect to the following criteria: (1) accurately identifying the true edges while minimising the likelihood of false positives; (2) ensuring that the detected edges are as visually alike to the true edges into the original image as likely; and (3) ensuring that only a single false positive is generated for each true edge point. Sobel edge detection masks incorporate the information about the edges in the horizontal and vertical planes into a single metric. The masks look like this:

$$\underset{\text{Row Mask}}{\begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}} \qquad \underset{\text{Column Mask}}{\begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}}$$

Each of these masks is convolved with the corresponding picture. A row mask result (S1) and a column mask result (S2) are now available for each pixel position. Using these values, one gets the following definitions for the edge magnitude and edge direction matrices:

$$\text{Edge Magnitude} = \sqrt{(S1^2 + S2^2)} \tag{1}$$

$$\text{Edge Direction} = Tan^{-1}\left[\frac{S1}{S2}\right] \tag{2}$$

6 Proposed system

The purpose of this work is to hide any medical significance in the picture. To begin the encryption procedure, the bits of the medical picture undergo a series of diffusions and modifications to get a scrambling condition helpful for gaining access to the maximal blurring of the image; the Sobel filter is then used to identify the edges. The edge image is a two-by-two matrix whose cells are individually divided into 3*3 squares, and then their values are transformed to integers. Since there are 9 bits per window, the highest possible integer number is 767, which indicates that there can only be a maximum of three significant digits in an integer. Then, the total of each group of three decimal places is added to the sum of the neighbouring groups, and the average of these integer values is converted into binary to serve as the key for the encryption procedure. The created key is XORed with each window of the edge picture and then subjected to NIST randomness tests to verify its legitimacy. The proposed approach for encrypting the medical images is elucidated in both algorithm 1 and Figure 1.

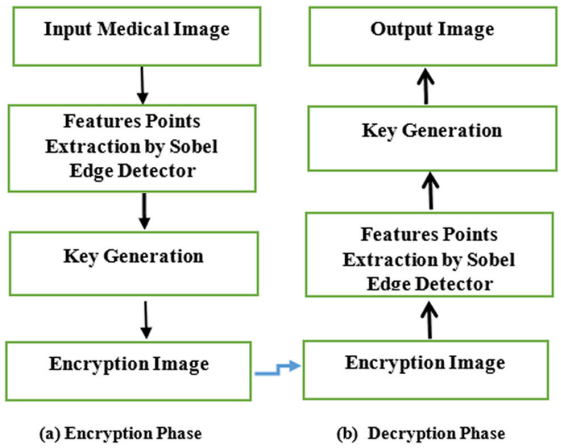


Fig. 1. The general stages of the proposed medical image encryption technique

Algorithm (1) General algorithm
Input: Original Image Output: Encryption Image Begin Step_1. Convert the original image into edge image using Sobel edge. Step_2. Convert the edge image into binary two-dimensional array. Step_3. Divide the array in the previous step to windows of (3×3). Step_4. Each window in the previous step is converted into an integer no., each number isn't exceeded 3 decimals places. Step_5. Create 1D array for storing the nos. made in the preceding step, each number has 3 cells from 1D array. Step_6. Sum each three cells in the previous step with the adjacent three cells and so on until the end of array Step_7. Calculate the average resulting in the previous step. Step_8. Convert the result of the previous step to binary bits, these bits represent the key generated for encryption process. Step_9. Xored the generated key with all the windows in the matrix of edge image in step 3. Step_10. The result of the previous step is the encryption image. End

6.1 Feature extraction by Sobel edge detector

Since Sobel edge detection is so efficient at extracting structural information from a wide range of visual objects, and since it greatly reduces the amount of data to be processed, it is utilised to locate the feature points, as manifested in Figure 2. After using the Sobel technique, the selected pixel is represented as a feature extraction vector.

The following steps are applied to extract a feature by Sobel edge detector:

- Transform the image into grayscale
- Convolve the grey image with Sobel-x filter
- Convolve the grey image with Sobel-y filter
- Compute the gradient magnitude and direction

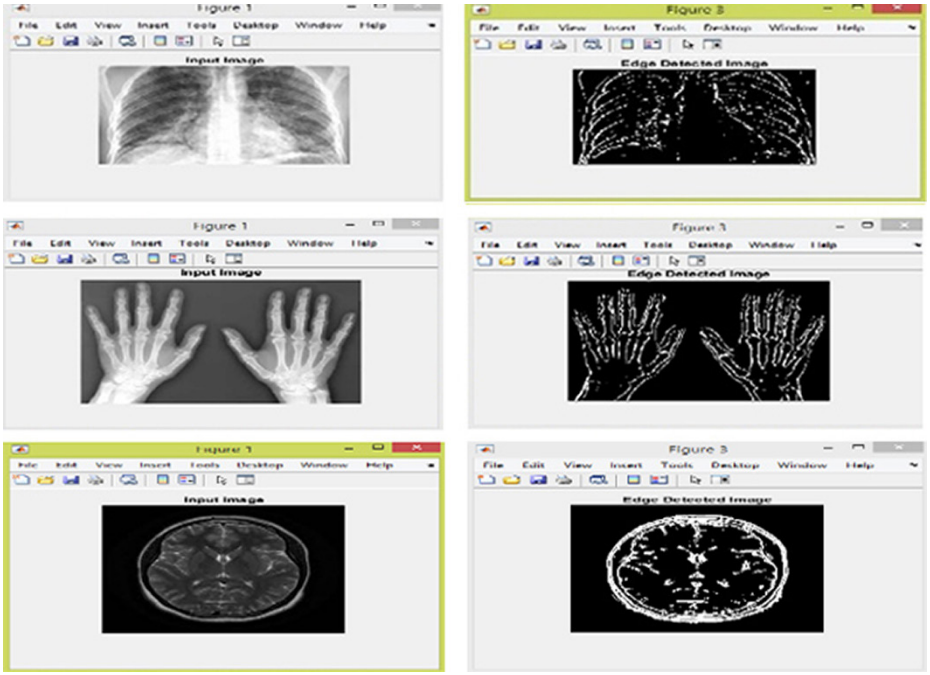


Fig. 2. Sobel edge detector

6.2 Key generation

Several security studies agree that generating random keys is the most crucial step in the encryption process. This is due to that an arbitrarily created long key being problematic to remember and, hence, tough to break. The feature extraction vector is used to generate a random cryptographic key (K), as evinced in Algorithm 2. The key generation is followed by testing for randomness. All produced keys have successfully passed the unexpected binary series and the random test; therefore, they can be used effectively.

Algorithm (2): Random Key Generator
Input: Image of Edge Detection Output: randomly key Begin Step_1 Create a binary matrix from edge detection of image (Figure 3(a)). Step_2 Divide the binary 2-dimentional array into size of (3*3) window, each one is equal to (9) cells, as depicted in Figure 3(b). Step_3 Convert the binary value of each window in Figure 3(c) into integer numbers, the value of this number is not exceeding 511. Step_4 Create one-dimension array, put the result of each window of step_3 in successive three cells, and this will be illustrated in the Figure 3(d). Step_5 Compute the average of all numbers in cells of Figure 3(d), as described in Figure 3(e). Step_6 Create one-dimension binary array by converting the average of cells in Figure 3(e) in the preceding step, such binary array refers as the key for the operation of encryption, and this will be revealed in the Figure 3(f). End

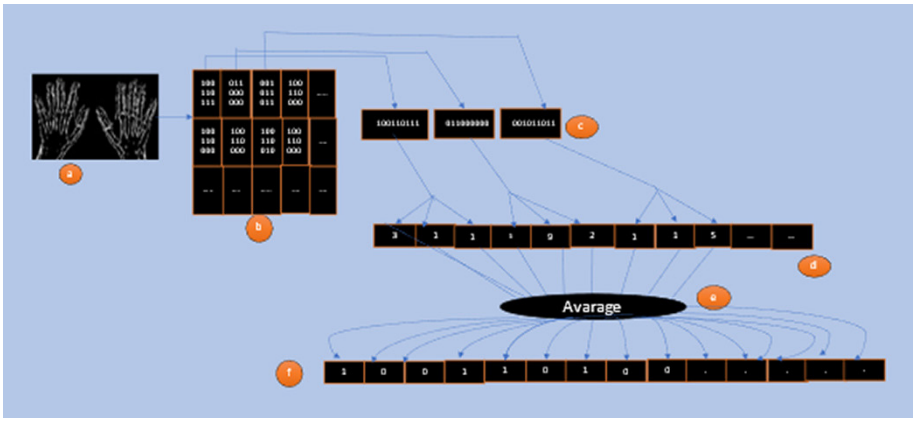


Fig. 3. Key generation: "a" An edge image, "b" 2D array, "c" 9 Bits window, "d" 1D of cells, "e" Average, and "f" Binary array (Key)

6.3 Medical image encryption

After the encryption equation has been fully implemented, the encrypted picture will be displayed in the second stage of the encryption process, where the key obtained using the Sobel technique will be utilised in the first step.

Algorithm (3) illustrates the steps of medical image encryption.

Algorithm 3: Medical Image Encryption.
Input: Points of vector features and key generation Output: Image encryption Begin Step_1: Apply the key created as clarified in the Figure 3(f) with a window, as illustrated in the Figure 4 (b) by using XOR operator. Ci=e(i) XOR b(i) Step_2: The result is image encryption. End

7 Experimental results

The suggested technique can be utilized for encrypting the images of each size or kind. As portrayed in the Figure 4a–d, three samples from medical images have been processed via the suggested procedure.

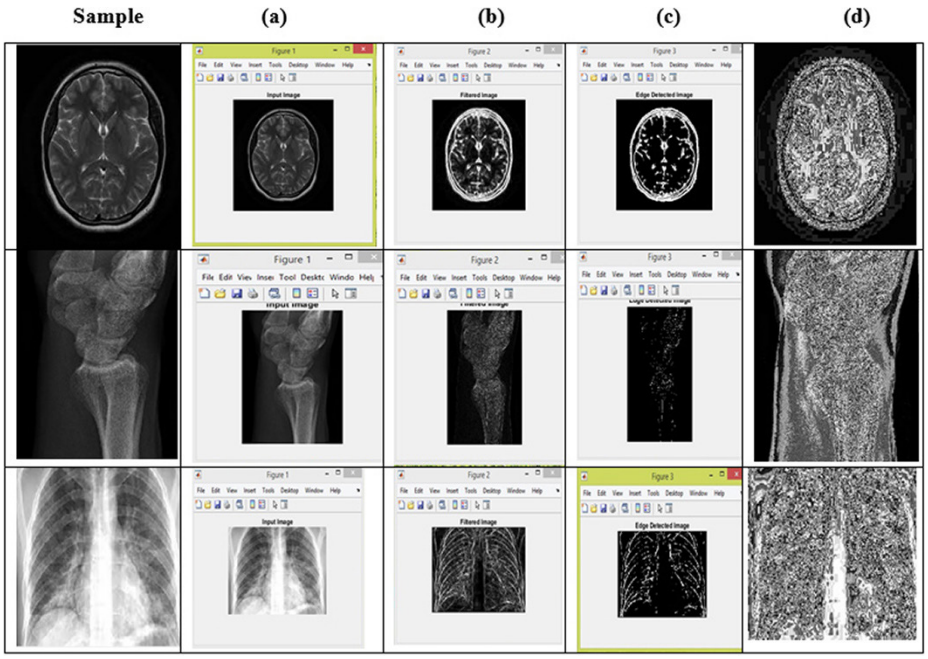


Fig. 4. Three samples from medical images, (a) Input image, (b) Filtered image, (c) Sobel detector apply, and (d) Image Encryption

The measures that being utilized to asset the proposal performance include NPCR, Medical image encryption time, Correlation as pointed out Equation **3** [32], Entropy Coefficient as pointed out Equation 4, UACI [32], and Equation 5 reference to Peak Signal to Noise Ratio (PSNR).

$$Rxy = \frac{1/N \sum_{i=1}^{N} (xi - 1/N\ \Sigma_{k=0}^{n} x(k))(yi - 1/N\ \Sigma_{k=0}^{n} y(k))}{\sqrt{\frac{1}{N}\Sigma_{k=0}^{n}(xk - E(x))^2}\sqrt{\frac{1}{N}\Sigma_{k=0}^{n}(yk - E(y))^2}} \tag{3}$$

$$\text{Entropy} = \Sigma(p(i))\left(\log\frac{1}{p(i)}\right) \tag{4}$$

Where:
P(i): Probability of the count of an ith image gray value

$$PSNR = 10Log10\left[\frac{M \times N255^2}{\Sigma_{m-1}^{M}\Sigma_{n=1}^{N}|\int(m.n) - \int d(m,n)|^2}\right] \tag{5}$$

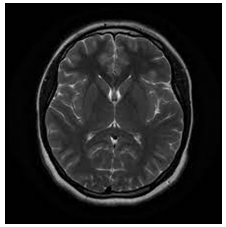
Where:
f (m, n): The original- image
(m, n): The decrypted-image
The suggested key generator yields a high resilience, as listed in Table 1, when applied to four randomization tests on three medical pictures. All four of these tests (Serial, Poker, Runs, and Frequency) demonstrated similar results.

Table 1. Four randomness tests for three medical images

Test		Accept Degree	Sample 1	Sample 2	Sample 3
Serial Test		Should be <=6.3	3.27.250	1.542	1.078
Poker Test		Should be <=11.1	4.300	0.725	1.263
Runs Test	**T0**	Should be <=15.391	12.321	8.329	7.654
	T1		1.341	2.361	1.561
Frequency Test		Should be >=0.001	0.134	0.109	0.126

Table 2 shows the encrypted and encrypted time, the image, Correlation, entropy, NPCR, PSNR, UACI, MSE for the encryption, and the decryption images, correspondingly, as well as the values of entropy for various samples of medical images.

Table 2. Evolution measurements for three medical image encryptions

Medical Image (Samples)	Encryption Time Full Image(Second)	Entropy Medical Image	Correlation	NPCR	UACI	MSE (Medical Image Encryption)	PSNR (Medical Image Encryption)	PSNR (Medical Image Decryption)
	4.89	7.42	0.653	68.52	8.108	64.48	19.3	85.17
	5.03	7.55	0.762	62.38	8.946	70.50	21.1	81.3
	4.65	7.45	0.628	68.136	10.729	65.82	19.7	83.74

8 Conclusions

In this research, the main objective of the process of encrypting medical images is to protect the data of healthcare institutions, customers or employees and any other information stored electronically from any type of cyber-attack. Where, the key was improved by the Sobel edge detection algorithm in addition to that a set of measures was used to calculate the degree of key strength by calculating the Entropy, Correlation, NPCR and UACI. The results were 7.42, 0.653, 68.52 and 8.108, respectively for sample (1a), and this indicates the degree of strength of encryption which ensures the degree of confidentiality. The encrypted image and also when retrieving the original image by doing the process of decrypting, the image turned out to be the image of a high quality and did not induce any loss of information during the process of encryption and decryption.

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Gait Recognition Using Convolutional Neural Network

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Abstract—Biometrics are the body measurements and calculations related to individuals. Biometrics validation is used as a form of identification of individual. Gait recognition system is one of the most advanced technology that people have been working on for a while now that takes center stage in the field of biometrics. Compared to the other types of existing systems of biometric recognition such as fingerprint detection, iris-scanning systems etc., Gait Recognition system ensures no human intervention. This paper focuses on recognition based on a person's gait. Every person has a distinct gait pattern that is unique to every other person. To train the model CASIA-B dataset has been used. The dataset includes 124 subjects where each sample has undergone Gait Energy Image extraction. Samples with clothing and baggage have been included which changes the silhouette of the person. Therefore, the model has been trained for a wider application where people wear different type of clothing and carry-ons. A Convolutional Neural Network consisting of 8 layers has been trained which performs well on both samples of dataset and an accuracy of 95.45% was obtained on dataset not involving layers of clothing and accuracy of 91.80% was obtained for the sample with clothing and baggage.

Keywords—gait recognition, GEI, convolutional neural network, CASIA

1 Introduction

The process of measuring and analysing the unique and special physical and behavioral characteristics of a specific person and using them to verify his or her identity is known as biometrics. Gait is one of the most distinct characteristics among human beings and hence can be used in biometrics to confirm and corroborate the identity of a person. Gait primarily means a person's way of walking. It is a pattern of steps and corresponding movement of the body that is unique to each person. Using this characteristic of the human body, one can distinguish different people. Different models can be trained using multiple types of technology available to achieve a good accuracy in recognizing different people based on their gait. The aim is to create a recognition system that accurately recognizes the person in question.

Gait recognition using video imagery approach involves study and research involving analysis of video samples of a person's walk and the trajectories of joints and angles. The motion is converted into a mathematical model and is devised and compared with

various other samples to arrive at conclusions. There are other models implemented such as Deep Convolution Neural Network (CNN) which is altered and adapted for recognition with Image Augmentation (IA) technique dependent on gait features [1]. In addition, another model has been introduced uses Gait Pal and Pal Entropy (GPPE) image which has been generated and united with four proposed distances [2].

Gait recognition systems find a great deal of scope in watching for shoplifters, criminals, and maintaining security at railway stations or airports. Therefore, it has been observed that this technology has maximum use mainly in the security sector although it also finds use in other applications as well such as identifying people at malls, violent protests and public places. In the proposed work an improvised version of GEI (Gait Energy Image) based gait recognition system using neural network to obtain better results than existing recognition system has been implemented. The gait energy image is one of the most well performing method to store the gait information from a sequence. The accuracy of gait recognition greatly depends on other covariates such as the viewing angle, carrying a bag, walking speed and occlusion of clothing [3, 4]. GEI represents human motion walking sequence in a single image while retaining spatial and temporal information [5]. Scenarios such as when a person wears multiple layers of clothes such as coats or jackets or carrying bags, which affects the overall silhouette of the person, which in turn can change the gait has been taken into consideration. In addition to this, the orientation of the person with respect to the camera or the recording device has also been considered to increase the robustness.

2 Relevant work

Bari et al. [6] have proposed joint relative cosine dissimilarity and relative triangle area. Adam optimization method is used to minimize the loss. The neural network is implemented on a three-dimensional skeleton gait dataset obtained using the Microsoft Kinect Sensors. Deng et al. [7] discusses a deterministic learning and knowledge fusion-based method to make the system view-invariant thus making it a more efficient gait recognition system. The nonlinear dynamics and the width feature of the person is approximated through deterministic learning algorithm. Su et al. [8] have considered hands and limbs move as the main features. Discrete Cosine analysis is used to analyse the dynamic characteristics and shape and with that they intend to reduce the gait features. They use multi-class SVMs to distinguish the different gaits of a human. Liao et al. [9] proposes the model known as PoseGait. This model is said to take human 3D pose estimated from images by CNN as the input for gait identification. The method proposed has been evaluated on CASIA-A and CASIA-B datasets.

Wu et al. [10] studies an approach to gait recognition using similarity learning by deep CNNs. They have tested using different network architectures, different pre-processing techniques on datasets like CASIA-B, OU-ISIR (Large Gait Dataset) and USF gait dataset. Yao et al. [11] have proposed Skeleton Gait Energy Image (SGEI) based upon the skeleton points extracted from a two-branch multi-stage CNN network. Sokolova et al. [12] have proposed a Pose based Gait recognition system. They have considered additional information of the movement of points in the areas around human joints as one of their important features and have not considered the full height of the silhouette.

Lishani et al. [13] discusses a gait identification system that selects various features for gait identification with various conditions like normal walking, with luggage and clothes for various angles. It mainly focuses on two feature extraction methods which are multi-scale local binary pattern and gabor filter bank. Singh et al. [14] have surveyed on the developments made in the field of human gait recognition. They also take us through historical research in the field of gait recognition and walks us through on how gait recognition or identification is performed. They describe features and metrics that can be used in gait recognition model and also provides information on gait databases available which are used in various gait identification system.

Tafazzoli et al. [15] explore the scope of the gait features extracted from different body parts of a human. The recognition is done with K-nearest neighbour classifier and also with the help of other scientific tools like Fourier components. Bhargavas et al. [16] propose to build an automatic biometric system to identify a person based on their Gait. They have proposed to implement the same by recognizing the subject from a video frame and using the skeleton information. Babaee et al. [17] have proposed a method using a gait recognition algorithm from an incomplete gait cycle. Wang et al [18]. have implemented a new type of gait assessment system based on the measures of gait variability imitated through the variability of shapes of the gait cycles trajectories. Chaitanya et al [19]. have mainly focused on recognition and identification of the genuine user of the smartphone and thus information theft is prevented by continuous authentication. The subject is recognized by analysing the physiological or behavioural attributes. Qiu et al [20] have proposed ensemble empirical mode decomposition method to analyse and recognize gait motions for subjects who are using an exoskeleton for motion. The intrinsic mode functions (IMF) were extracted using the original signals by EEMD which are then fed to classification algorithms to recognize. It is found that there are some similarities between IMF and the gait of a person. The experiments were conducted on 14 people. It is seen that some algorithms perform very well on the data such as logistic regression, Kmeans, Naive Bayes, decision tree, random forest methods and SVM. The subjects are made to walk on different floor materials with varying friction and see how it affects the gait. It is found that this has very little effect on the gait of a person.

Huan et al [21] makes use of acceleration sensors in smartphones and explores a way to analyze the gait of a person. Si et al [22]. have made use of remote sensing system for security area monitoring which collects signals from people walking towards the system where the data of their walking and face is extracted and is processed to recognize the person. Systems such as GRF (Ground Reaction Force) are employed which helps to find the force exerted on the floor when the person is walking and a camera is used to capture the image of face. The face detection signals and the gait signals are merged together to get better accuracy when performing the classification and it provides a more robust system. The extracted features have been used as input to GRF identification system and the face recognition was performed using SVM classifier.

Zhou et al [23]. have proposed a model based on Long Short-Term Memory (LSTM) and is combined with orthogonalization method to separate out and enhance the generalization ability of the model for different groups and follow the exoskeleton more precisely. A CNN was used to extract features related to personal information and the LSTM is used to extract features based on the gait. This is done by

using cosine similarity. Elharrouss et al [24] have used a method to perform person re-identification via gait recognition which involves calculating the angle of the gait first and then this information is used to recognize the person through convolutional neural network. Then this GEI and the CNN is used to calculate the angle of the gait and recognize the person. Datasets like CASIA-B, OUMVLP and OU-ISIR have been used for testing and training purposes. This has been evaluated using Scene Background Modeling and initialization dataset.

Gao et al [25]. have proposed an improved system which combines artificial bee colony and combination of multiple features as a way to optimize support vector machines (SVM). Features like variance, number of zero-crossing and sEMG, median frequency, fuzzy entropy features and wavelet features are extracted to use as the feature set for the SVM to work on. They have talked about the influence of different classifiers and features on the results and a new penalty coefficient is employed along with a kernel function parameter of SVM. The SVM is trained on the feature set obtained using the algorithms and it is found that the classifier performs 3.18% better than that of non-optimized SVM. Zou et al [26]. have proposed CNN for gait identification and the data is collected using Inertial sensors in smartphones. The data collected using smartphones is subjected to Gait Data Extraction and then subjected to Gait Cycle segmentation and fed to CNN for the result. They have developed an Android application to be installed on smartphones to collect data and then the data is sent to LSTM, CNN based system which performs the authentication into the application.

Sepas-Moghaddam et al [27]. have presented a survey upon the various technologies, methodologies and approaches that have been in use or can be used to perform Gait recognition. Comparison of various fields such as datasets (CASIA-A, CASIA-B), representations of Gait such as body, temporal representation and various neural network architectures and types that can be used to perform Gait recognition has been listed with the performance metrics. Ng et al [28] have proposed a Gait recognition system in which SOTON small database has been used. Multi-view Normalization and Viewpoint Normalization has been used to perform the data extraction after which five-point angular trajectories have been extracted on five main limb joints, then four classification techniques have been used such as SVM, BPANN, Fuzzy k-nearest neighbour and LDA for classification. Luo et al [29] have proposed a Gait system in which gait recognition is performed by using GEI and also AFDEI (Accumulated Frame Difference Energy Image) which considers the time frame unlike GEI. The Gait classification is performed using nearest neighbour classifier upon the AFDEI.

Kim et. al [30] have presented work related to Gait recognition system using a Microsoft Kinect Camera to capture the images and the Gait data is extracted from the Kinect device. Features of the body would be captured by Kinect camera upon which extraction would be performed to extract joint angles. Balazia et. al [31]. have proposed a gait system which learns distinctive gait features via raw MoCap data. After the collection of data all the templates are stored in the central database. Classification of an individual is done by capturing that persons walk and comparing the obtained template with any matching template that is already existing in the database. Hanqing chao et. al [32] have implemented a CNN based gait recognition system upon the CASIA-B dataset. Their algorithm called Gaitset performs Set Pooling to collect gait information.

3 Proposed system

The CASIA-B dataset was considered for the proposed work. The CNN model has been used to form the architecture of the recognition system.

3.1 Input data

Firstly, CASIA-B dataset consists of photos, which includes 124 male and female subjects with 11 different views i.e. the angle at which the subject is oriented with respect to the camera. The dataset consists of 6 normal walking samples, 2 samples carrying baggage and 2 samples with extra layer of clothing per subject. In this dataset unimpaired gait or pathological gait is not included. It also includes variations such as people with multiple layers of clothing such as coats and carrying baggage like backpacks which impacts the silhouette.

In gait representation, Gait Energy Image (GEI) is provided as the input to the CNN, which is extracted by separating out the silhouette of human and then averaged upon the sequence of the silhouettes [24]. GEI is a very prominent way in the gait representation area as they capture both the spatial and temporal information. It is also advantageous as it gives the human gait cycle in a single image. Experimentally they have proven that GEI is a robust and efficient type of gait representation [5].

$$G(x, y) = \frac{1}{N}\sum_{t=1}^{N} I(x, y, t) \tag{1}$$

Using Equation 1 the Gait Energy Image can be calculated where N specifies the total number of frames in one gait cycle, I(x, y, t) is the gait cycle image sequence, coordinate of the image is specified by x and y, t stands for total frames in a gait cycle.

GEIs contains information about dynamic walking environment and the silhouette. Before calculating and computing the GEIs, background subtraction and normalization are used to fetch the gait sequences.

Fig. 1. GEI sequence sample

A GEI sequence for a subject for various angles is given in Figure 1. Images needs to be augmented for better performance [33], therefore GEIs were then normalized using Keras ImageDataGenerator to get the grayscale value of each image as it makes all the input images have similar data distribution.

The training dataset consisted of 4 samples of normal walking sequence and 1 with baggage and 1 with extra layers of clothing for all the views. The test data consisted of 2 samples of normal walking sequence and 1 carrying baggage and 1 with extra layers of clothing. After train-test split of the dataset, 7657 images were used for the training dataset and 4945 were used for the test dataset belonging to 124 classes.

3.2 CNN

Convolutional neural network has played a crucial role in the advancement of deep learning and image recognition. CNN has proven to be a very efficient way to create classification models [34] and has many advantages over other image recognition methods. It was developed by taking inspiration from the visual cortex of the brain. CNN often requires very little image pre-processing compared to all the different algorithms.

Activation function in neural networks help in introducing non-linearity into the model. It is often required in problems involving non-linear solution. ReLu function was decided to be used as the activation function for the CNN. Equation 2 gives the ReLu function.

$$f(x) = \begin{cases} 0, & x < 0 \\ x, & x \geq 0 \end{cases} \tag{2}$$

The ReLU is a mathematical function that will output the maximum of input directly if it is positive or else it will output zero. An output is equivalent to zero when the input value is negative, as shown in equation 2. Additionally, L2 regularization was used which penalizes the loss function on the squared magnitude of sum of all weights of a neural network. Regularization is often used to avoid overfitting and complexity of the model. The magnitude of penalization depends on the hyperparameters specified. In the proposed work regularization rate of 0.0005 was used for the model.

Optimizers are algorithms that change the attributes such as weights and bias to minimize the loss function using a specified learning rate. Adam Optimizer was ideal because it has the best parts of RMSprop algorithm and deals very well with noisy problems. Learning rate of 0.001 was found to be best for the model to converge.

3.3 Architecture

The training images were sent to the CNN to perform the next steps of pre-processing using its convolutional layers and the CNN model was trained on the created input dataset.

The proposed work has a CNN with 8-layer architecture with 3 convolutional layers, 3 pooling layers, 1 fully connected layer and finally a softmax layer as shown in Figure 2. The convolutional layers help to find patterns in the data. The pooling layers decrease the number of features so that the model can learn more efficiently. In the past, CNN has delivered good results in the field of image recognition.

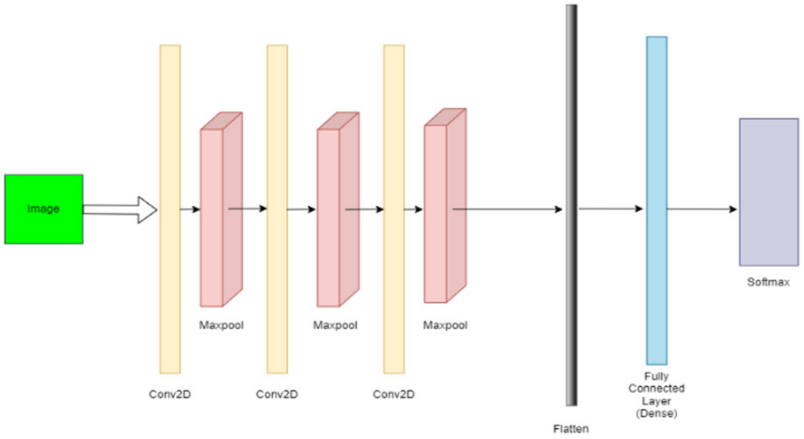

Fig. 2. CNN model architecture

The training data was injected into the first convolutional layer (Conv2D) which has learnable filters that filter the data for necessary features. The output of the convolutional layer (feature map) was passed into maxpool layer which calculates the largest value patch in each feature map. Similarly, this process goes on between every convolutional layer and maxpool layer. After the last maxpool layer, the output was fed to a dense layer which flattens the output and sends it to the fully connected layer from where it is sent to softmax layer which squishes the output into one of the range of labels that was displayed to the user. After the model was trained, it was tested using the test set to obtain the accuracy of the model. Finally, the trained CNN model was be able to classify people in the dataset based on their gait.

Pseudocode:
START
Step 1: *Input data* ← split (train data and test data)
Step 2: Normalize the *Input data* ← rescale and convert to grayscale
Step 3: Build the neural network
Step 4: Train the network with ReLu activation and Adam optimizer
Step 5: Test the network with test dataset
END

4 Results and discussion

Table 1 gives a comparison on the accuracy obtained by the proposed work and other researchers using CASIA-B data set.

Table 1. Results in different conditions for CASIA dataset

Method	Normal (Without Clothes and Bag)	Normal (With Clothes and Bag)
WideResNet [32]	100.0%	89.4%
VGG + blocks [12]	94.5%	65.1%
Gait with CNN [proposed]	95.45%	91.8%

In Table 1, it is observed from comparing the results obtained by a model that is using WideResNet [32] which presents an accuracy of 100% without clothes and bag and 89.4% with clothes and bag. The other model that is using VGG+Blocks [12], L1 which presents an accuracy of 94.5% without clothes and bag and 65.1% with clothes and bag. The proposed gait recognition system using CNN performs well in both cases with accuracies of 95.45% and 91.8% respectively and hence with accuracy of above 90% in both cases.

Table 2. Comparison of average recognition rates for 90º angle on the CASIA dataset

Method	90 Degree View %
WideResNet (PCA 230) [32]	68.8%
Gait with CNN, [proposed]	96.37%

In Table 2, it can be observed that the results obtained by a model using WideResNet (PCA 230) [32], for a 90-degree view of the subject was 68.8% when compared with the proposed model which gives an accuracy of 96.37% for the same view.

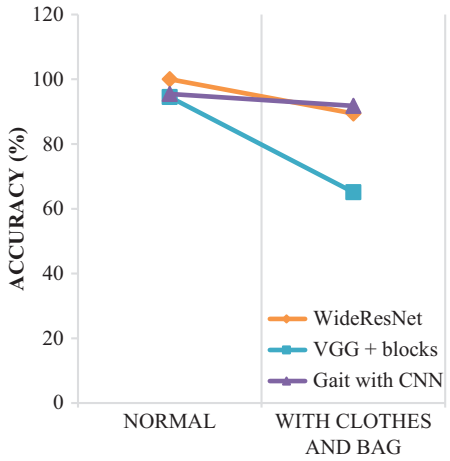

Fig. 3. Comparison of deviation in accuracies for normal and with clothes and bag

As observed in Figure 3, the proposed model which is represented by the line ending with triangles which can be seen as having minimum deviation between the accuracies of both the datasets (normal and with clothes and bag), when compared with diamond and square lines which represent the accuracies of [32] and [12] respectively. Therefore, it can be said that the proposed model has better accuracy for a dataset containing a wide range of variations compared to other models that include clothing and baggage and thus is more robust.

Methods such as "evaluate" (averages successful labels for the test data) in Keras library was used to test the model and obtain the accuracy, loss and other performance metrics. The model which was tested using 248 single-view (90°) images obtained an accuracy of 96.37% using the evaluate function. Later the same model was tested on multi-view images which did not include clothing and baggage scenarios for which accuracy of 95.45% was achieved. The model achieved an accuracy of 91.8% with clothing and baggage which had the complete CASIA B dataset. The predictions were compared with the true labels of the test dataset to plot the confusion matrix. The confusion matrix will help to see how well the model is performing on the whole dataset. After analyzing the results from testing it could be determined that using 0° and 180° angle images did not contribute to the model accuracy instead it reduced the total accuracy of the model as the difference between GEIs for these angles was minimal.

5 Conclusion

The proposed work builds a model to recognize a person based upon their gait, which can be implemented further in real-time applications. Gait Recognition can be beneficial to identify a person from a distance without his/her knowledge, which would prove to be advantageous for security surveillance or during a pandemic. The model was trained on CASIA-B dataset in normal walking condition, and it covered 11 different angles. Using a CNN of 8 layers the model was able to achieve acceptable results for both single-view and multi-view data. For single-view dataset, the model was able to achieve an accuracy of 95.45% using ReLU as the activation function. In addition, an accuracy of 91.8% was obtained for multi-view dataset including clothing and baggage scenarios with ReLU activation function. Training for multi-view data is beneficial since all the angles of gait are covered unlike the case of single view, where the model has to be trained for all the angles each time separately depending on the angle.

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Private Backend Server Software-Based Telehealthcare Tracking and Monitoring System

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Abstract—In these recent years, the world has witnessed a kind of social exclusion and the inability to communicate directly due to the Corona Virus Covid 19 (COVID-19) pandemic, and the consequent difficulty of communicating with patients with hospitals led to the need to use modern technology to solve and facilitate the problem of people communicating with each other. healthcare has made many remarkable developments through the Internet of things (IoT) and cloud computing to monitor real-time patients' data, which has enabled many patients' lives to be saved. This paper presents the design and implementation of a Private Backend Server Software based on an IoT health monitoring system concerned with emergency medical services utilizing biosensors to detect multi-vital signs of an individual with an ESP32 microcontroller board and IoT cloud. The device displays the vital data, which is then uploaded to a cloud server for storage and analysis over an IoT network. Vital data is received from the cloud server and shown on the IoT medical client dashboard for remote monitoring. The proposed system allows users to ameliorate healthcare jeopardy and minify its costs by re-cording, gathering, sharing, and analyzing vast biodata streams such as Intensive Care Units (ICU) (i.e., temperature, heartbeat rate (HR), Oxygen level (SPO2), etc.), efficiently in real-time. In this proposal, the data is sent from sensors fixed in the patient body to the Web and Mobile App continually in real time for collection and analysis. The system showed impressive performance with an average disparity of less than 1%. body temperature, SPO2, and HR readings were remarkably accurate compared to the CE approval patient monitoring system. In Addition, The system was highly dependable with a success rate for IoT data broadcasts.

Keywords—Internet of Things (IoT), Wireless Body Area Sensor Networks (WBASN), COVID-19, artificial intelligence (AI), cloud computing

1 Introduction

The coronavirus disease (COVID-19) epidemic is the most serious threat to humanity in recent years and the most significant global health issue [1]. Globally, there have been about 514 million confirmed cases of COVID-19, including about 6.3 million deaths,

according to the World Health Organization's (WHO)infections of 6 May 2022 [2]. The SARS-CoV-2 virus is the infectious virus responsible for COVID-19 [3]. The virus is transmitted by contacting a contaminated surface or by the respiratory droplets of an infected person. Symptoms can include a high fever, cough, difficulty breathing, and body aches according to the Centers for Disease Control (CDC) [4][5]. Sometimes, patients do not recognize the symptoms and cause subsequently die without receiving proper treatment Therefore, it is important for persons to regularly check up on their health conditions, especially body temperature, HR, and SpO2. but due to the imposing quarantine which was identified as an efficient measure to curb the spread of the virus worldwide. it may be difficult for most people to get regular health checkup appointments, specifically for oldsters (over 60) and individuals who have weak immune systems or chronic disease issues [6].

One solution to decrease the disease's spread by taking early diagnostic steps and reducing the effect of the disease's symptoms while staying at their home with the help of the Potential Infected Patient Monitoring (PIPM)process [7][8]. PIPM is achieved by utilizing the Internet of Things (IoT) with Wireless Wearable Health Devices (WWHDS) [9]. WWHDS consists of several sensor nodes placed on or implanted in a human body that record the patient's vital signs such as temperature, O2 saturation, HR, and other respiratory information [11][12]. IoT devices are microcontrollers that collect, analyze, and monitor the WWHDS biodata and then manage and store the disease symptoms remotely in the cloud via the Internet and then transferred them to a healthcare center where clinicians can investigate the information via their web or phone application to identify abnormal activities and send precautions to patients on time before severe damage [13][14]. As a result, IoT systems improve the COVID-19 healthcare system by being utilized to track medical supplies convey, and send and receive medical data through wearables. Therefore, Doctors can more easily examine, diagnose, and treat patients by utilizing IoT-based telemedicine technology without physical contact [10]. Figure 1 illustrates the IoT with cloud-based COVID-19 patient health monitoring.

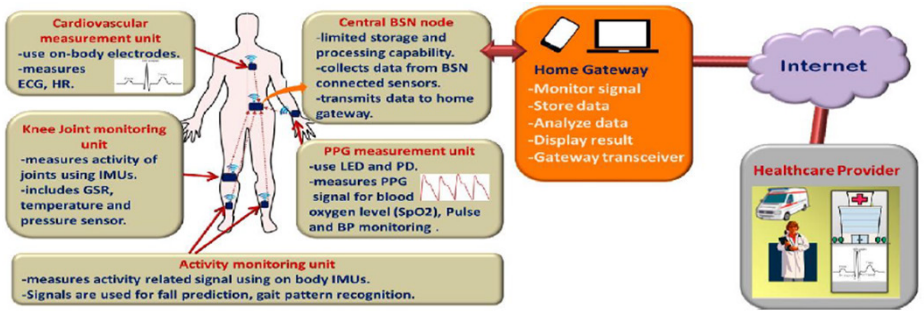


Fig. 1. The architecture of a wearable health-monitoring system

In recent years, IoT has rapidly developed by integrated with artificial intelligence (AI) techniques to enhance intelligence, modality, and care [15]. many wearable IoT devices (WIoT) were developed such as microsensors that are embedded in various costume parts (such as t-shirts, glasses, or belts), computerized watches, etc. [16].

Many designs and researches are related to the continuous health monitoring system, which describes the vital signs among the most crucial physiological signals of the human body. Valerie GAY et al. [17] designed a smartphone and wearable sensors for monitoring the ECG trace in real time. they used wireless and smartphones to analyze the high risk of cardiac. They classified the solutions into two groups: The first group uses smartphones with biomedical sensors to measure heart activity and then transmits these signals to the hospital. The second group designed a device for real-time remote monitoring. In this study, the heart rate detector has a sensitivity value of 99.4% when compared to the patient monitor system. Y. Baptista et al. [18] used A web application remote health-monitoring system based on Enterprise Service Bus (ESB). they used Web services interfaces to expose the transmitted data to the monitoring influx within the ESB and smartphone gateway placed with the patient to work as a data sink for on-body Wireless Body Area Networks (WBAN) sensors worn by the patient. they used Simple reasoning processes executed by the smartphone application before broadcasting the collected data to the monitoring system through the Internet.

H. Jianqiang et al. [19] designed a Cloud assisted home health monitoring system. they used a smartphone and Xiamen Health Cloud to receive vital signals and store them. the system gives positive import to chronic diseases patients that allow health monitoring and services from home. Fajar M.R. et al. [20] studied the effect of heart health on the human body. The researchers show aside from the ECG, heart health can be specified by measuring the blood pressure of the subject. Blood pressure in some patients show a good result, thus the health of some patient cannot be immediately diagnosed at the healthcare Centre. For this reason, the need of continuous monitoring of blood pressure is needed. In this study, the researchers designed a mobile blood pressure for real-time measuring the blood pressure and automatically sent the data to the doctor or hospital via SMS. The device was smart and fast transmitted the data; it will take about 46.27 seconds for each measurement. Kadave A.R etc. [21] utilized the internet of things (IoT) to monitor patients' multiple characteristics. they transferred real-time parameters to the cloud through connect the monitoring device to the internet. they suggested a tool linked to a computer wirelessly that provides real-time monitoring and is managed by the patient. the result demonstrates the significance of measuring vital signals during activity and moving medium to check a patient's health. Dong et al. [22] designed a wearable device for continuous blood pressure (CBP) monitoring [23], but it did not keep health data for further study. Aadil et al. [24] proposed a wireless body area network (WBAN) for remote health monitoring that utilized the IoT. Li et al. [25] created a ZigBee network to connect devices to a base station. Fu et al. [26] used a wireless sensor network and a Wi-Fi transmission protocol to evaluate oxygen saturation, although he looks at only one indicator, making it difficult to evaluate overall health. Raileanu et al. [27] analyzed the questionnaires anonymously on an internet platform after analyzing the MAST (Model for Assessment of Telemedicine) in the Cardiology department. The application passed the MAST test, proving that the created telemedicine solution for cardiac patients serves its secondary prevention goal. Sabukunze et al. [28] proposed an IoT concept for smart malaria patient monitoring and alert systems. They concluded that a smart monitoring and alert system is critical for monitoring malaria patients and can warn them in the event of a serious situation. Nagarjuna et al. [29] discussed the real-time temperature and humidity

monitoring scenario. They conclude that the critical scenario can be averted and preventive measures successfully taken by using a Virtual Instrumentation (VI) server and a data gathering web application using a regular web browser.

This paper uses web and mobile apps with ESP32 microcontrollers and biosensors to monitor patients' status. The collective parameters related to the severe problem are collected from the patient. This data given to two different interfaces included vital parameters and displayed details. This collected data is given to a web-based server as well as a mobile app, so the presented data can be checked by the doctors at any time with the help of their computer or smartphone, it helps them to examine and send precautions to patients and their family members at the same app, at the same time reminding them to take his medication on time before severe damage [30]. IoT plays an important role which offers live, fair, and comprehensive monitoring taking the edge off the patient's governess support to make medical assistance [31].

This study is organized as follows. In Section 2 the wearable is described by providing the specifications of instrumental sensors for its development besides the algorithmic process adopted is presented. Section 3 includes the results stemming from the present study. Lastly, in Section 4, concluding remarks and discussion on future research steps are provided.

2 Materials and methods

This system proposed wireless sensor implementation for 24*7 and provides health parameters by monitoring them without interrupting daily routine. For this fixed and mobile body sensors are used with a desperate algorithm. This helps for positing and analyzing patients' health and to take additional decisions about patient health. The given architectural model is in the Figure 2 shows the basic structure of the presented technique, in which the MLX90614 sensor is used to detect the fever and the MAX30100 sensor to detect oxygen level and heartbeat then their output sends to ESP32 Ardunio. The messages can be read by web or android app on the computer or smartphone of the patient's doctor and caretaker to assist them and at the same time, the patient's health history is also has been saved on a cloud database.

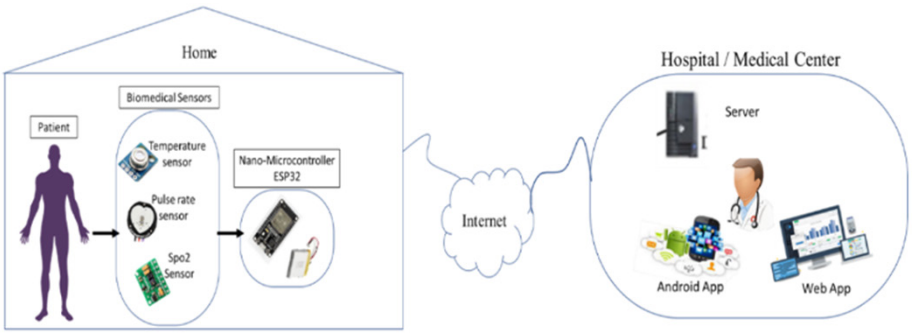


Fig. 2. The architecture of biosensors for remote healthcare monitoring system

The design of the system consists of three stages. The first stage is the hardware components which consist of (a microcontroller, biosensors, and server for both mobile and web applications) as shown in Figure 3. A second stage is the software REQUIREMENTS that program these biosensors to connect to the microcontroller and monitor the parameters and finally, in the third stage all of the systems are packaged in one small device to be wearable to the patient.

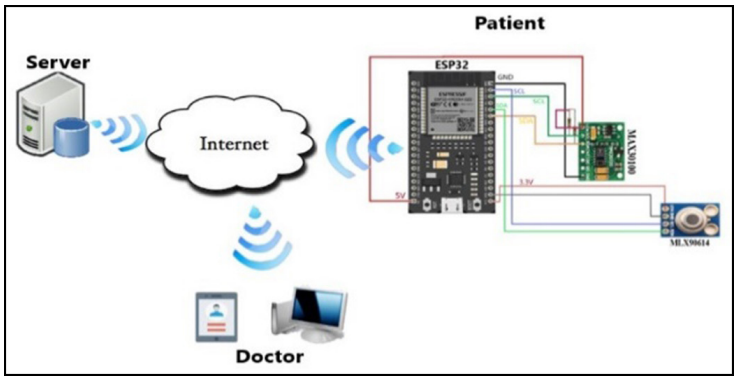


Fig. 3. The schematic diagram for the hardware configuration

2.1 Hardware components

ESP32 microcontroller. ESP32 shown in Figure 4 is low power and low-cost microcontroller chip designed by Espressif in Shanghai, China. It has integrated Wi-Fi with dual-mode Bluetooth radios. It has many of the capabilities of the Arduino that is programmed using the Arduino IDE software and so is a soft upgrade path for applications that needs wireless communication. The ESP32 is an upgrade of the earlier ESP8266 and adds a faster dual-core processor and Bluetooth interface. In the proposed system, ESP32 considers the core of the system which is used to collect the patient's vital signs via biosensors and then process the data and sent it via WIFI network to a central server that allows displaying the data on the mobile and web applications for both patient and doctor.

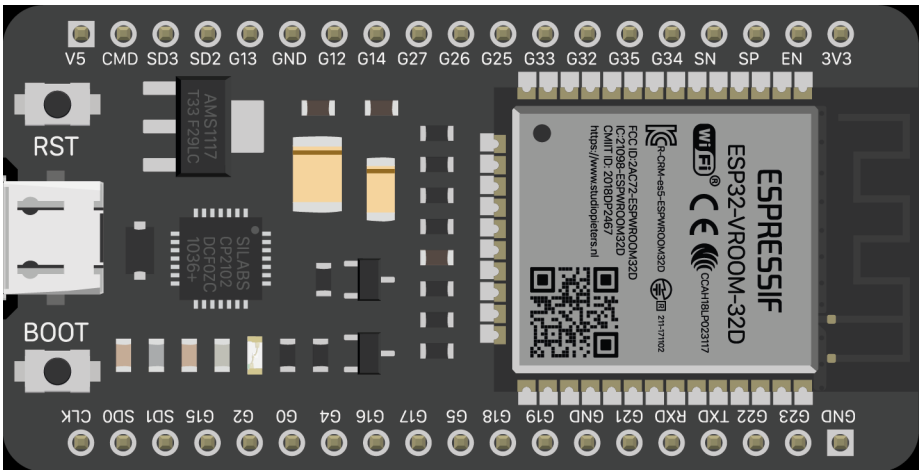


Fig. 4. ESP32 with Nodemcu

MAX30100. The MAX30100 is a sensor used to measure the heartbeats per minute and the concentration of oxygen in the blood. The sensor has two LEDs; one is used to emit infrared light to measure heart rate and the other to emit red light to measure with the first the SPO2 in blood. It has seven pins each one has its function as shown in Figure 5 [32].

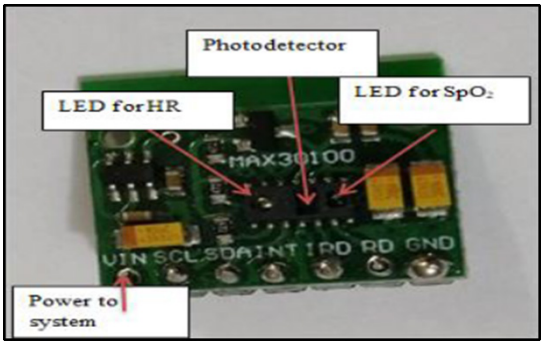


Fig. 5. The MAX30100 pins description

Auto calculate the percentage of oxygen saturation follow the formula at eq.1

$$Spo2 = 110 - 25\left(\frac{RED\ LED\ Level}{IR\ LED\ Level}\right) \tag{1}$$

MLX90614. MLX90614 as shown in Figure 6 is a temperature measurement device that works on infrared radiations. It is the best option for such applications because it provides non-contact measurement of temperature. It consists of a squatnoise amplifier, 17-bits Analog-to-Digital and an efficient digital signal processor (DSP) component.

These components give the sensor a high accuracy and degree. this sensor uses an infrared light detector with Advanced Solid-State Photonics (ASSP) signal conditioner for processing the output [33].

Fig. 6. The MLX90614 pins description

Server. A server is a computer system that makes resources, information, services, or programs available across a network to other computers or mobile devices known as clients. Theoretically, computers are regarded as servers whenever they share resources with client devices as illustrated in Figure 7. Web servers, mail servers, mobile servers, and other sorts of servers are only a few examples. In the proposed system, this hardware part is used to build web and mobile services to be used by both the patient and doctor to view the patient's information on their computer or phone.

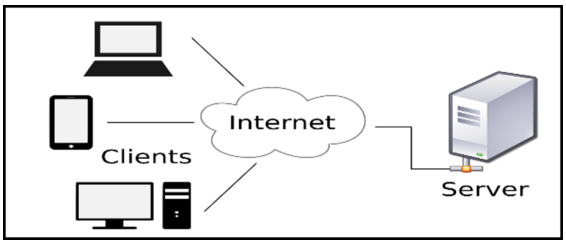


Fig. 7. A diagram of a computer network showing a client connecting to a server computer over the Internet

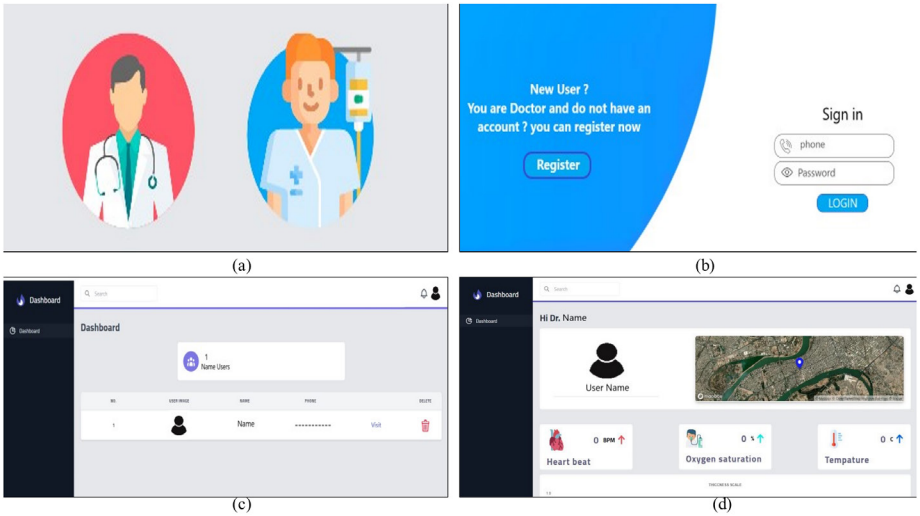
2.2 Software requirements

The Integrated Development Environment (IDE) is a cross-platform (Windows, macOS, Linux) application written in C and C++ functions. It's used to program microcontroller-compatible boards and upload them.

Web application. Nowadays, the number of Web Frameworks has increased greatly. It can safely accelerate and extend work, including allowing the production of a responsive and more attractive web app. Because so many web frameworks currently rely on Modules, View, and Controller (MVC), ReactJs was chosen to design and run the web application as shown in Figure 8. React makes creating interactive user interfaces (UIs) a breeze. it will update and render only the necessary components as the data changes, it is used by FACEBOOK. Declarative sights make coding more predictable and debugging easier. Also, React is used to create mobile applications (React Native). React employs one-way data binding and the Flux application architecture, which manages the flow of data to components through a single point of control.

Fig. 8. Run react app

The application consists of a page that defines the user as a doctor or patient, a login page, a dashboard that sees all patients roll with their doctor, and a page for monitoring patients provided by graph history as shown in Figure 9.



(a) (b) (c) (d)

Fig. 9. (a) User page, (b) Login page, (c) DashBoard, (d) Monitoring Page

For a mobile application as shown in the Figure 10, A flutter framework is used to develop a native cross-app. Framework Widget Library is used to create things like user interfaces and building blocks. Then with the help of the Software Development Kit (SDK) convert the app created into native machine code.

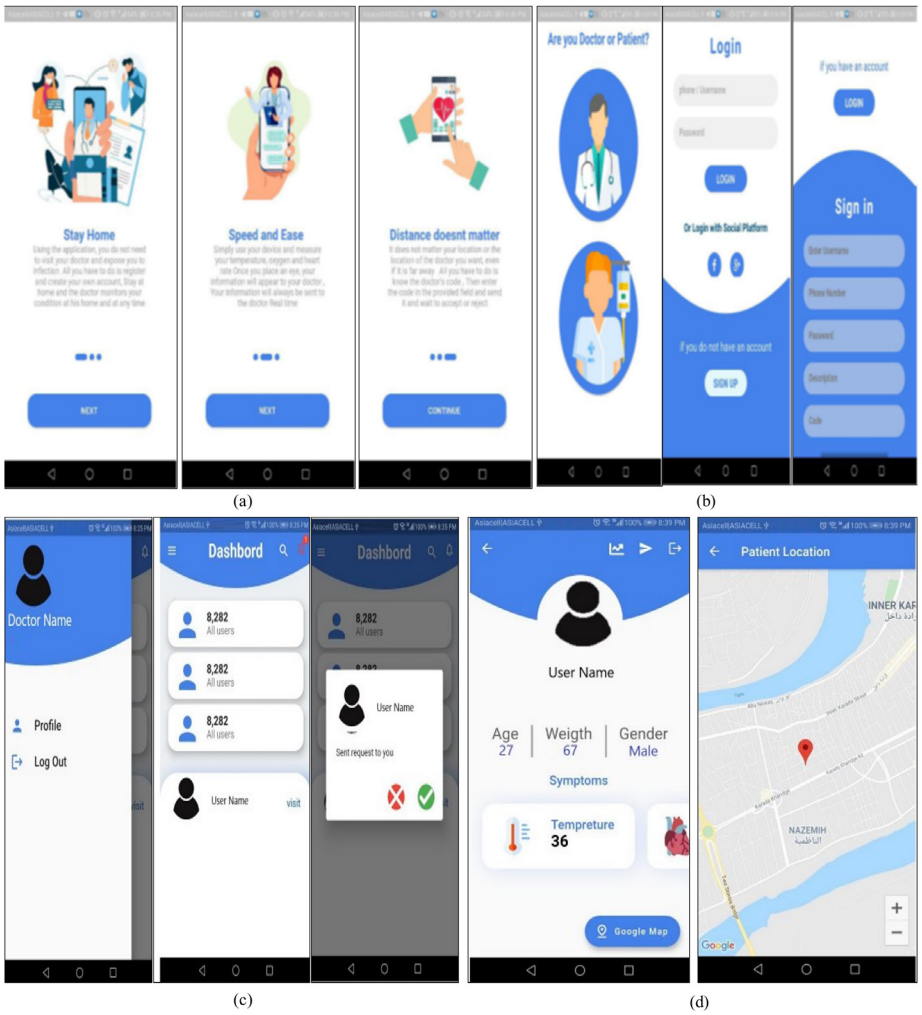


Fig. 10. (a) Onboarding pages (b) Login and Sign in (c) Dashboard for doctor and how to receive a request (d) Patient Profile and his location

3 Results and discussion

The validation of the present system was achieved by comparing the results of the proposed system with the patient monitoring system that is used in the hospital (CE approval). The results were obtained from 17 subjects (some of them healthy and the others are severed from some disease) of different sex and ages. The results of the vital signs of the human body were obtained from two sources, the first one is the data obtained from the IDE software and CE approval patient monitoring system as illustrated in Table 1.

Table 1. Results of 17 subjects are obtained from the IDE software compared with CE approval patient monitoring system

Pt.	IDE Software			CE Approval Patient Monitoring System		
	SPO2	Temp. (°C)	HR	SPO2	Temp. (°C)	HR
1	96	35.8	81	97	36.4	82
2	98	36.3	83	99	36	84
3	97	36	86	96	36.3	85
4	96	36.2	80	97	36	81
5	96	36.3	80	97	36.7	79
6	96	36.1	79	97	36.3	78
7	95	36.4	69	96	36	68
8	98	35.6	78	99	35.8	79
9	97	36.5	80	96	36.2	81
10	98	35.5	87	97	35.9	88
11	96	36	80	97	35.8	81
12	97	36.2	80	98	36.4	79
13	96	36.5	77	97	36.3	76
14	95	36.1	75	96	36.4	74
15	96	36.6	87	97	36.2	86
16	98	35.9	88	99	35.8	87
17	95	36.1	75	96	36.3	74

As illustrated the results are very approximate in all vital signs (SPO2, Temp., and HR). So the device has the ability for detecting any changes that been happened to the patient directly. Table 2 shows the measuring of the percentage errors of the present system against the CE approval device. This is done by using the equation: [34]

$$Error\,(\%) = \frac{MV - CV}{CV} \times 100\% \tag{2}$$

Table 2. The measuring of the errors (%) of the present system against the CE approval device

Pt.	SPO2 (%)	Temp. (%)	HR (%)
1	1.031	1.648	1.220
2	1.010	0.833	1.190
3	1.042	0.826	1.176
4	1.031	0.556	1.235
5	1.031	1.090	1.266
6	1.031	0.551	1.282
7	1.042	1.111	1.471
8	1.010	0.559	1.266
9	1.042	0.829	1.235
10	1.031	1.114	1.136
11	1.031	0.559	1.235
12	1.020	0.549	1.266
13	1.031	0.551	1.316
14	1.042	0.824	1.351
15	1.031	1.105	1.163
16	1.010	0.279	1.149
17	1.042	0.551	1.351

Where MV is the measured value of the present device and CV is the controller value of the CE approval device. The second result of the vital signs of the human body was obtained from the IoT spatial software (Thinger.io program) as illustrated in Table 3.

Table 3. Results of 17 subjects are obtained from the IoT software

Pt.	SPO2	Temp. (°C)	HR
1	96	35.8	81
2	98	36.3	83
3	97	36	86
4	96	36.2	80
5	96	36.3	80
6	96	36.1	79
7	95	36.4	69
8	98	35.6	78
9	97	36.5	80
10	98	35.5	87
11	96	36	80
12	97	36.2	80
13	96	36.5	77
14	95	36.1	75
15	96	36.6	87
16	98	35.9	88
17	95	36.1	75

As illustrated in Figure 11, the resulting data transferred through the network from the IDE software and IoT spatial software are synchronized in real-time and matched. Therefore, the doctors can diagnose any change that will occur in the vital sign.

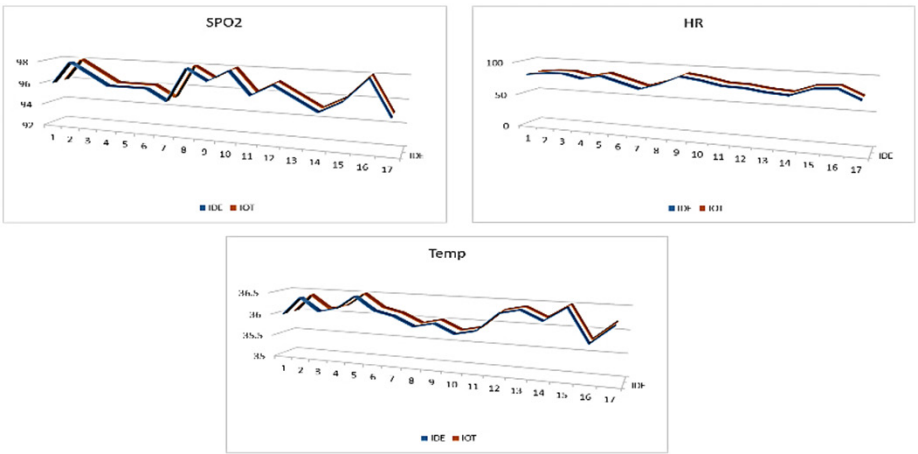


Fig. 11. Data obtained from the IDE software and IoT spatial software

4 Conclusion

This research presents a design and implementation of a Private Backend Server Software based on an IoT health monitoring system concerned emergency medical services and other health issues of COVID-19 patients' monitoring utilizing biosensors to detect multi vital signs of an individual with an ESP32 microcontroller board and IoT cloud. The proposed system is efficient, and economical, and allows continuous faraway Healthcare for patients with COVID-19, the Intensive care unit (ICU), or also the ever-increasing demography of elders. The proposed system enables hospitals and medical centers to continue storing and monitoring patients' vital medical signs like fever, oxygen level, heart rate, etc. while staying at their home. At any abnormality, it gives an alert to the centers, and medical staff or specialist doctors can monitor, localize, and instruct patients online. likewise, patients can ask their queries to their remote doctors too. In the proposed system the data can be made available for remote use and only to authorized users, such as distant specialist doctors and specified patients. As a result, design parameters such as availability, security, correctness, and efficiency are successfully met. The given results of observations have been shown successfully with high accuracy, precision, and gain. The system showed impressive performance with an average disparity of less than 1%. body temperature, SPO2, and HR readings were remarkably accurate compared to the CE approval patient monitoring system. In Addition, the system was highly dependable, with a success rate for IoT data broadcasts. In future work, it is possible to improve the system accuracy by utilizing blockchain technology and trying to make the wearable gadget smaller to make them more user-friendly. Also, Cyber-attacks can compromise IoT devices. As a result, data traveling from the system to the cloud must be coded, and implement security strategies to prevent cyber-attack.

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Sentiment Analysis for People's Opinions about COVID-19 Using LSTM and CNN Models

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Abstract—The emergence of social media platforms, which contributed in activating the patterns of connection between individuals, leads to the availability of a huge amount of content such as text, images, and videos. Twitter is one of the most popular platforms of social media that encourage researchers to investigate people's feelings and opinions among through sentiment analysis studies that elicited the interest of researchers in natural language processing field. Many techniques related to machine learning and deep learning models could be used to improve the efficiency and performance of sentiment analysis, especially in complex classification problems. In this paper, different models of long short-term memory recurrent neural network are used for the sentiment classification task. The input text was represented as vectors using Arabic pre-trained word embedding (Aravec). Experiments were conducted using different dimensions of Aravec on 15779 tweets about COVID-19 collected and labeled as positive and negative. The experimental results show an accuracy value of 98%.

Keywords—Arabic sentiment analysis, Aravec word embedding, convolutional neural network, deep learning, long short term memory, COVID-19

1 Introduction

The pandemic caused by COVID-19 resulted in outbreaks and lockdowns around the world. Since its emergence in the end of 2019, the pandemic affected people's lives in different fields, such as social life, psychological, learning and teaching, healthcare, and finance [1] [47]. During this phase, people used social media platforms, such as Twitter and Facebook, to express their feelings and opinions about the current situation, thereby encouraging researchers to investigate people's feelings among these social platforms through sentiment analysis studies [2]. However, Twitter is considered as one of the most popular social platforms, because of its availability and ease of knowledge exchange [3]. During the pandemic, people have turned to social media sites to continue their social connections despite the lockdowns and restrictions imposed by governments, which in turn increased the use of these social networks by 61% [4].

Sentiment analysis that is also known as sentiment classification or opinion mining, is a text-mining approach that analyzes and extracts subjective information from a text to transform unstructured text into meaningful and valuable information [48].

It is one of NLP applications that needs machine learning algorithms as the classification process [49]. It is considered a complex process with five steps, which begins with collecting data and continues with preprocessing text, detecting sentiment, and classifying text into positive, negative, and other categories. The final step is to present the output [2], [5].

D'Andrea et al. classified the techniques applied for sentiment analysis [5] into three categories, namely, lexicon-based, machine learning (ML), and hybrid approaches that incorporate both ML and lexicon-based approaches. ML approaches split the data into training and testing sets to predict the polarity of emotions, while the lexicon-based approaches work with a predetermined list of words, and each of which is linked to a certain emotion. Furthermore, ML approaches can be referred to as supervised learning, while lexicon-based approaches are referred to as unsupervised learning [6].

Recently, deep learning (DL) is used in the domain of natural language processing (NLP). One of the dominant methods of DL is the recurrent neural networks (RNNs), and the long short-term memory recurrent neural network (LSTM) is one of its gated versions used in different NLP applications, such as classification tasks, sentiment analysis, and many others.

This research proposes the use of different DL models, such as LSTM and convolutional neural networks (CNN) with Aravec embedding [7] to represent input words, the evaluation of the approach was performed using a collected dataset from Twitter social media and different Aravec representative models, such as Skip-gram and CBOW trained on tweets with vector dimensions of 300 and 100. The rest of this research is organized as follows; Section 2 represents previous related work. Section 3 explains methodology, concepts and background methods used in the experimented models. Then, a description for the conducted experiments and utilized dataset is shown in Section 4. In Section 5, a discussion for the results is provided. Then, we conclude in Section 6.

2 Related works

Several studies and experiments have been tested in sentiment analysis for Arabic texts. Biltawi et al. [8] presented a comprehensive survey of sentiment classification that was conducted on Arabic language. They classified 32 surveyed papers into three categories, namely, the lexicon-based, ML-based, and hybrid-based methods. According to this survey, social media platforms, including Twitter, are considered the most efficient data source for Arabic sentiment analysis research. They also considered that Arabic sentiment classification remains an open area for research.

Alwehaibi et al. [9] proposed an optimized sentiment classification for dialectal short text at Arabic document level. They extracted semantic features at the word and character levels for Arabic short text. Then, they utilized LSTM, CNN, and a model that combines both CNN and LSTM to improve the efficiency. They also applied a hyper parameter tuning estimation approach. To evaluate their approach, they used a dataset of dialectal Arabic corpus and modern standard Arabic collected from Twitter to train and

test the three models. The results reported an accuracy that ranged between 84% and 96.7% for all tested models. They also employ a loss value in the range of 0.29 and 3.4.

Biltawi et al. [10] proposed a hybrid model that combined the lexicon-based and the corpus-based approaches for Arabic text sentiment. They evaluated their model using two different datasets, the OCA and Twitter, and compared the results with that of the corpus-based approach. The hybrid approach outperformed the corpus-based approach with an accuracy of 96.34% using random forest with six-fold cross-validation.

In 2019, Biltawi et al. [11] proposed a fuzzy logic, lexicon-based approach to analyze sentiment in Arabic text. The authors verified their approach in two independent experiments using a large-scale Arabic book review dataset. The highest accuracy value achieved was 80.59%.

Ahmed et al. [12] analyzed Arabic tweets about COVID-19 for sentiments using five different ML models, namely, support vector machine (SVM), Naïve Bayes, random forest, logistic regression and K-Nearest neighbor. They evaluated the five models using Arabic Sentiment Twitter Corpus (ASTC) [13]. The results show that the k-NN model gains the lowest accuracy value of 63.23%, and the SVM model provides the best accuracy value of 84.14%.

Alturayeif and Luqman [2] used two transformer-based models, namely, AraBERT [14] and MARBERT [15], with a loss function that is weighted dynamically (DWLF) to analyze the sentiment of Arabic tweets. They evaluated their proposed method using SenWave and SenAIT datasets [16]. The results show that the proposed BERT-based models with emoji replacement and DWLF technique improved the sentiment classification of multi-dialect Arabic tweets with an F1-score value of 0.72.

Alhazmi and Alharbi [17] investigated the emotions twitted by Saudis during the COVID-19's final stage of lockdown. Then, they classified these emotions into eight categories such as fear, anger, trust, anticipation, surprise, joy, sadness, and disgust, as in NCR [18]. Also, they attempted to detect the changing dynamics of expressed emotions. The results show that although positive emotions predominated in the early ending stage, negative emotions were also noticed, mainly due to the uncertainty toward COVID-19.

AlZoubi et al. [19] developed several innovative techniques to analyze the emotion intensity of Arabic tweets. They used three DL models, namely, bidirectional GRU with CNN, CNN, and XGBoost regressor (XGB). To evaluate their proposed techniques, they use the dataset of SemEval-2018 Task1, which is a reference dataset with more than 1,169,075,128 tokens. The model resulted in a Pearson value of 69.2%, and an enhancement of 0.7% is also provided compared with previous best-performing state-of-the-art used models.

Albukhitan et al. [20] applied deep learning technology to produce semantic annotation for Arabic web resources. The proposed framework relies on one linking noun-phrases with concepts from a corresponding ontology. They used word embedding models and two matching verb-phrase methods and employed ontology relationships between concepts. Their approach is still emerging and needs more work to improve its performance.

However, convolutional neural networks (CNN) and long short-term memory (LSTM) have obtained extensive attention as promising methods for sentiment analysis.

For example, Heikal et al. [21] explored the performance of three DL models, namely, CNN, LSTM, and merged CNN-LSTM models with AraVec word embedding, to predict the sentiments of an Arabic Twitter dataset ASTD [22]. The ensemble CNN-LSTM model achieves the best F1 score with 64.46% value.

Also, Alayba et al. [23] attempted to study the advantages of combining two neural networks models on different Arabic sentiment datasets, Main Arabic Health Services (Main-AHS) dataset [24] and Sub-AHS dataset [25] by applying character N-Gram level (ch5gram) and word level sentiments. The proposed model achieved an accuracy value of 0.9424 when applied to the Main Arabic Health Services (Main-AHS) dataset with word-level sentiment while obtaining an accuracy value of 0.9568 when applied to the Sub-AHS dataset with Ch5-gram-level.

Meanwhile, other researchers compared the performance of traditional ML models with DL models. The results of their studies proved that DL models outperform ML models. For example, Elzayady et al. [26] compared three regular machine learning methods, K-Nearest Neighbor (KNN), Naïve Bayes, and DT with two deep learning models: LSTM and CNN. These techniques were applied to Arabic Hotel Reviews (HTL) dataset [27] and Arabic Book Reviews (LABR) dataset [28]. The results show that the combined CNN-LSTM model achieved a competitive average accuracy value of 86.88% and 85.83% when applied to LABR and HTL datasets, respectively. Oussous et al. [29] showed that the CNN and LSTM models on Moroccan Sentiment Analysis Corpus (MSAC) outperformed NB, SVM, and ME classifiers with different preprocessing techniques. Furthermore, Ombabi et al. [30] studied the performance of CNN and LSTM with different embedding models used for the input layer. The experiment was conducted on a multi-domain sentiment corpus [27] [28] where the best accuracy value (90.75%) was achieved when one CNN layer and two LSTM layers were applied with FastText skip-gram word embedding model. Alayba & Palade [31] proposed a CNN-LSTM model without the use of max-pooling layer with various word embedding models; GloVe, Word2Vec, and FastText. Also, they investigated various word normalization techniques, such as Madirma, Farasa, and Stanford. They evaluate their model using Arabic Health Services AHS dataset [25], Ar-Twitter dataset [32], and Arabic Sentiment Tweets Dataset (ASTD) [22]. Their model achieves accuracy value of 0.948 for Main-AHS dataset using Farasa Lemmatization, 0.889 for Ar-Twitter dataset using Madamira Stemming, and accuracy value of 0.8162 for the ASTD dataset using Word2Vec skip-gram embedding model with 200 dimension vectors.

A comparison among the previously mentioned related approaches in terms of reference, year, proposed method, dataset, evaluation metric, and results is shown in Table 1.

Table 1. Comparison of the methods proposed for Arabic sentiment

Paper	Year	Methods	Dataset	Data Size	Metric	Results
(AlZoubi, et al., 2020)	2020	Bidirectional GRU with CNN, CNN, and XGBoost regressor (XGB)	Arabic tweets dataset, Emotion Intensity Regression (EI-reg)	1,169,075,128 tokens	Pearson	69.2%
(Alturayeif & Luqman, 2021)	2021	Skip-Gram and CBOW	Arabic COVID-19 tweets.	13,019 tweets	F1-Score	0.72
(Alwehaibi, et al., 2021)	2021	LSTM, CNN, and an ensemble LSTM-CNN model	AraSenTi dataset	15 K balanced tweets	Accuracy	88%-69.7%
(Biltawi,et al., 2017)	2017	Random forest, Naive Bayes, SVM, Maximum Entropy, BAGGING, BOOSTING, Neural Network, Random Forest, and Decision Tree.	Opinion Corpus for Arabic (OCA) and Twitter	1000 text files in each folder, each file consists of a single review, shorter than the reviews in the OCA corpus.	Accuracy	96.34%
(Ahmed,et al., 2021)	2021	Naïve Bayes, Support Vector Machine, Logic Regression, Random Forest, and K-Nearest Neighbor	Arabic tweets related to COVID-19 Arabic Sentiment Twitter Corpus (ASTC)	58,000 Arabic tweets	Accuracy	84%
(Albukhitan, et al., 2020)	2020	Word2Vec CBOW and Skip-gram with Mean Vectorization and Cosine similarity	A collected set of documents related to Nutrition, Food, and Health.	150 Web documents	Precision Recall	80.6 80.8
(Heikal, et al., 2018)	2018	CNN, LSTM, Ensemble (CNN-LSTM)	Arabic Twitter dataset ASTD	10,000 tweets	Accuracy, F1-measure	65.05% 64.46 %

(Continued)

Table 1. Comparison of the methods proposed for Arabic sentiment *(Continued)*

Paper	Year	Methods	Dataset	Data Size	Metric	Results
(Alayba,et al., 2018)	2018	CNN-LSTM	Main-AHS Sub-AHS Ar-Twitter ASTD	2026 tweets 732 tweets 2000 tweets 54,000 tweets	Accuracy	94.24% 95.68 % 88.10 % 79.07 %
(Elzayady, et al., 2020)	2020	ML models: NB, (KNN), and decision trees DL models: LSTM and CNN	Arabic Hotel Reviews (HTL) Arabic Book Reviews (LABR)	15,000 Arabic reviews 16,448 book reviews	Accuracy	85,83% 86,88%
(Oussous, et al., 2020)	2020	ML models: NB, SVM, ME DL models: CNN and LSTM	Moroccan Sentiment Analysis Corpus (MSAC)	2,000 reviews	Accuracy	99% with CNN
(Ombabi, et al., 2020)	2020	CNN and LSTM	multi-domain sentiment corpus	15.100 training 4,000 testing	Accuracy	90.75%
(Alayba, et al., 2017)	2021	Ensemble (CNN & LSTM)	Main-AHS Sub-AHS Ar-Twitter dataset Arabic Sentiment Tweets Dataset (ASTD)	2026 tweets. 1732 tweets 2000 tweets 10,006 tweets	Accuracy	94.83% 96.8% 88.86 81.62%

While the studies mentioned above focused on applying deep learning and machine learning techniques to Arabic datasets, other studies used other techniques for English sentiment analysis; such as the capsule network that was investigated by Demotte et al. [51]. They proposed to use shallow, deep, and ensemble capsule networks for sentiment classification with two datasets collected from Twitter. They also explored the use of static and dynamic routing methods to enhance the accuracy of text classification. The results of their experiment show accuracy of 0.869 for Stanford Twitter Sentiment Gold dataset with the shallow capsule network, dynamic routing and crawl Glove word embedding.

However, some studies focused on other low resource languages, such as Sinhala. The work of Meedeniyal and Perera [52] evaluated the categorization of Sinhala documents by proposing a model based on Latent Semantic Analysis, Gaussian Mixture model, and k-means clustering while Lenadora et al. [53] tried to investigate the behavior of Sri Lankan people posts on Facebook during COVID-19, where the behavioral patterns, topic significance, and topics co-occurrence where analyzed.

In this research, we proposed to use different deep learning models with LSTM and CNN for Arabic sentiment classification task on COVID-19 tweets with two classes, namely, positive and negative. Also, we employed CBOW and Skip-gram Aravec pre-trained vectors as input to the models.

3 Methodology

Four deep learning models are proposed to be applied to Arabic sentiment analysis based on text representation methods and DL methods. The techniques that constructed the proposed models are described in the following subsections.

3.1 Word embedding

Word embedding refers to a representation that captures the semantic relations between words. Each word is implemented as a vector of real numbers in the dimensional space where words with similar vector representations would be considered semantically similar.

AraVec refers to a pre-trained word embedding model for Arabic [18]. AraVec has 16 different learning word embedding models that have been trained using Twitter and Arabic articles from Wikipedia with vector dimensions of 100 and 300 [33] [54]. These articles and tweets are trained using an adapted version of Word2Vec models [34], the CBOW, and the skip-gram.

To obtain results with higher accuracy, we used AraVec word embedding as an embedding input layer for the tested DL models where each word is used as an input in a sequence.

3.2 Long short term memory networks (LSTM)

LSTM network is a special version of the recurrent neural network. It has been designed to overcome the problem of vanishing /exploding gradient [35] that occurs in RNN [50], and it has the ability to learn better long-term dependencies [36].

LSTM can remember information from the past through its ability to remove or add information to a memory cell state based on the context of input. The LSTM cell is controlled and regulated by three binary gates, namely, forget gate f_t, input gate i_t, and output gate o_t. Equations (1), (2), (3), (4), (5), and (6) represent the forget gate, the input gate, the activation function, cell state, output gate, and the output h_t. Having x_t is the input for each time-step, h_{t-1} is the output from the previous LSTM unit also called hidden unit, and c_{t-1} is the memory of previous unit.

$$f_t = \sigma\left(W_f.\left[h_{t-1}, x_t\right] + b_f\right) \tag{1}$$

$$i_t = \sigma\left(W_i.\left[h_{t-1}, x_t\right] + b_i\right) \tag{2}$$

$$p_t = \tan\left(W_p.\left[h_{t-1}, x_t\right] + b_p\right) \tag{3}$$

$$c_t = f_t \times c_{t-1} + i_t \times p_t \tag{4}$$

$$o_t = \sigma\left(W_o.\left[h_{t-1}, x_t\right] + b_o\right) \tag{5}$$

$$h_t = o_t \times \tan\left(c_t\right) \tag{6}$$

Where:

f_t is the forget gate

i_t, is the input gate

o_t is the output gate

h_{t-1} is the output from the LSTM previous unit

x_t is the input for each time-step

c_t is the cell state at timestamp t

c_{t-1} is the memory of the previous unit

p_t is the activation function

W_f, W_i, W_p, W_o are the weights for the forget, input, activation, and output gate neurons respectively.

σ is the sigmoid function.

b_f, b_i, b_p, b_o are the biases for the forget, input, activation, and output gates, respectively.

Figure 1 shows the relations between these gates in a single LSTM unit where the forget gate controls how much of the old state has to be forgotten by using sigmoid activation function. The output refers to a number between 0 and 1 where the value of "zero" indicates forget while the value of "1" means keep. The input gate controls the new information that updates the memory cell state. It employs a sigmoid function to

decide what values to be updated and utilizes *tanh* function to create a vector of new candidates that can be added. These two output values are combined to update the cell state. The final value on the output gate decides what information should hold to the next cell state [37].

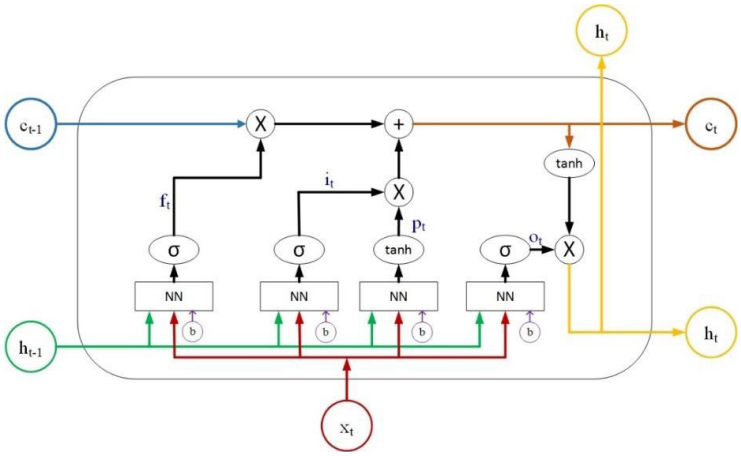


Fig. 1. LSTM unit [38]

3.3 Convolutional neural networks (CNNs)

The basic principle of CNNs or ConvNet is the convolution operation. CNNs are popularly used for image analysis, they have some type of specialization for being able to select and detect specific patterns from images, especially in sequence processing, computer vision, as well as certain NLP tasks [39] such as sentiment analysis which is a widespread used application of CNNs [40].

CNN can have more than one-dimensional convolution layer according to the type of data. When CNNs are applied to texts instead of images, one-dimensional layer is usually used to extract features because texts are considered sequential data. However, the main concept remains the same for both data types [41].

The most suitable NLP application of ConvNet is the classifications task. For example, sentiment classification can detect the patterns in a sentence regardless of their position by considering the n-grams, characters, or sequence of characters [42].

A word embedding layer and a one-dimensional convolutional network are required to use CNN for text data. In the embedding layer, each word in a sentence is converted into a word embedding vector. Then, the vector is padded to obtain equal dimensions for all vectors in the matrices [43]. The convolutional layer receives input as embedded word vectors and detects the features by applying filters to each possible window of words in the sentence. The result is one representative vector for the whole sentence. Next, convolved features are generated by passing vectors to a pooling layer for the further sampling of output and for capturing the prominent features [44].

The pooling operation is used to reduce computation power by reducing the dimensionality of features. The pooling layer combines the vectors generated from different

convolution windows into one-dimensional vector by taking the maximum value or the average pooling value, which will keep the most prominent features in a sentence. Subsequently, the vector is fed into a fully connected layer to perform its intended classification task [45].

3.4 Proposed models

This section presents the four models that have been evaluated through the experiments. The differences among these models are determined by adding a new element each time to the current model, and as a result four models were experimented.

Model 1: is an LSTM model and consists of the three layers as illustrated in Figure 2.

Word embedding layer: pre-trained AraVec word embedding is used to convert the tweets into numeric format.

LSTM layer: comprises of a stack of LSTMs, with a number of hidden units equal to 100, which reads a single element of the input sequence in each time step, collects information from it and proceeds to the next time step. The input sequence is the tweet $X = \{x_1, x_2, \ldots, x_J\}$. At each time step, the hidden states $h_j^x \in \mathrm{R}$, for the tweet and illustrated in Equation 7.

$$h_t^x = f\left(h_{t-1}^x, x_t\right) \tag{7}$$

where f can be a non-linear function or even an LSTM. The last hidden state encapsulates a summary of the input sequence that is sent to the output layer.

Output layer: where the output is computed using Sigmoid with dense layer.

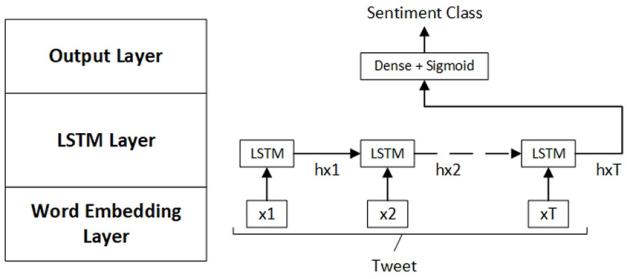


Fig. 2. Represents the architecture of model 1

Model 2: is LSTM model as well. However, dropout is added to the model to prevent it from overfitting. It consists of the same three layers. However, dropout of 0.2 is added before the LSTM layer.

Model 3: corresponds to an update of model 2 and consists of the same three layers and dropout of 0.2. The only difference is in the hidden units where it is increased into 150 units. The architectures of models 2 and 3 are illustrated in Figure 3.

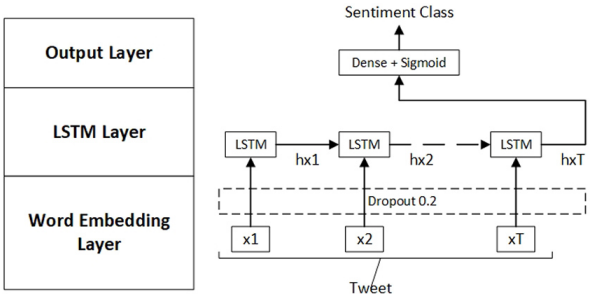


Fig. 3. Architecture of models 2 and 3

Model 4: is a four layers model that comprises LSTM and CNN as illustrated in Figure 4. The four layers are described as follows:

Word embedding layer: pre-trained AraVec is used to convert the tweets into vectors with numeric format, and a dropout of 0.2 is used to prevent the model from overfitting.

CNN layer: consists of 1D convolutional and Maxpooling operations.

LSTM layer: represents the same LSTM layers discussed in Model 1 with 150 hidden units.

Output layer: the output is computed using Sigmoid with dense layer.

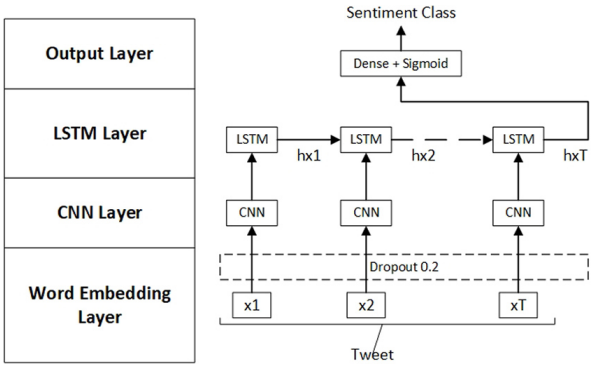


Fig. 4. Architecture of model 4

In the embedding layer of the four models and after loading the dataset, the maximum length of the tweets is computed, and a vocabulary is built where the vocab size is computed. Next, word-to-index dictionary is created to convert the tweets into vectors using the dictionary, and the short tweets were padded with zeros. Then, the embedding matrix is created using the AraVec.

4 Experiments and dataset

In this research, four DL models are applied to Arabic sentiment analysis for COVID-19 tweets dataset. The tweets are classified into two categories, namely, positive and

negative. In the following subsections, more details are provided for the dataset, experimental settings and results.

4.1 Dataset

We generated our dataset by collecting Arabic tweets from Twitter regarding people's reactions to the COVID-19 pandemic. The collected dataset consists of 15779 Arabic tweets that indicate people's perceptions on the seriousness of the coronavirus. Then, the collected tweets are labeled manually by human annotators using two labels, namely, positive or negative. As a result, 12,176 tweets are labeled as positive, and 3,613 tweets are labeled as negative, which indicates an imbalanced dataset where the number of positive tweets is greater than the number of tweets in the negative class as shown in Figure 5.

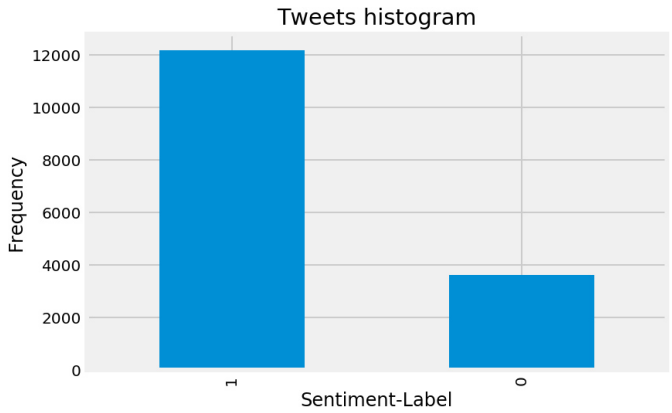


Fig. 5. Positive and negative tweets in COVID-19 labeled dataset

A sample image of the data record is shown in Figure 6 where each record consists of an Arabic tweet about COVID-19 and a label of 1 or 0, where label 1 indicates positive perception while zero indicates negative perception.

Arabic Tweet	Label
اخذت ناس كثير بكورونا وبدون كورونا اللهم ارحمهم واعفوا عنهم واجمعنا بهم بالفردوس الاعلي	1
ولد عمي الي مخالطه قبل فترهِ مصاب وانا فيني اعراض كورونا	1
كورونا تري هي كذبه اخترعوها الامريكان والصينين عشان حرب بيولوجيه فيروسيه بينهم ولا ما في شي	0
اتفق معاهِ غير ان الصحه العالميه جالسه تضخم الموضوع و الاعلام يعزز و الحقيقه انو كورونا خزعبلات	0
اخاف انزل من كورونا	1
اخذنا خادمه وطلع عندهاكورونا حسبنا الله ونعم الوكيل	1
ازمه كورونا علمتنا قيمه العناق الاخير	1
اصابه احس اغلبهم فيهم حرارهِ عاديه مو كورونا	0

Fig. 6. A sample image of the data record in Arabic COVID-19 dataset

4.2 Data initialization and sampling

The collected tweets require a preprocessing step to fit the intended sentiment analysis task [46]. Preprocessing includes the removal of unwanted data, such as duplicate tweets, hash tags, HTML tags, URL links, numeric data, emoji, diacritics, punctuation marks, and special characters.

The next step is to divide the dataset into two sets, namely, training set and testing set. The training set represents 70% of the tweets in the dataset, which is sampled randomly from the total data while the testing set represents 30% of the dataset and sampled randomly considering the percentage of records labeled as negative and positive. The result in this stage is 4737 randomly sampled records for testing, and 11052 records are left for training. Table 2 shows the statistics of the training and testing sets in terms of the negative and positive classes.

Table 2. Training and testing sets

Class	Training	Testing	Percentage	Total
Positive	8529	3647	77%	12,176
Negative	2523	1090	23%	3,613
Total	11,052	4,737	100%	15,789

4.3 Hyperparameters settings

This subsection presents the hyperparameters' settings for all experiments conducted in this research. The baseline experiments were conducted using Adam optimizer, its default initial learning rate (0.001) and a dropout of 0.2 while four batch sizes; 32, 64, 128, and 256 were investigated and the maximum number of epochs was 20 epochs. Early stopping was determined once the model performance stopped improving which was after three training epochs.

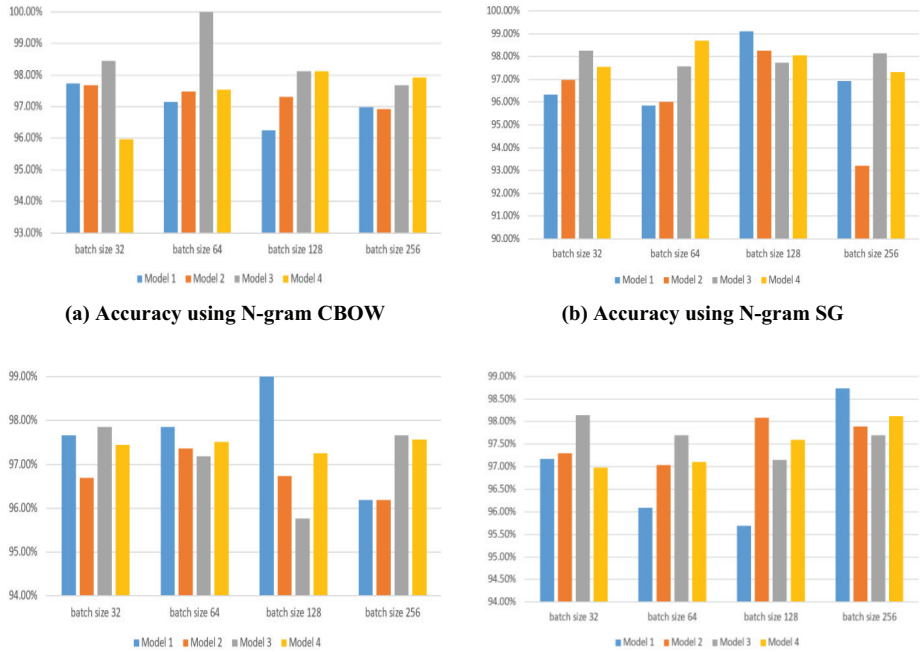
However, experimental tuning for hyperparameters was carried out, where the conducted experiments show that the maximum epoch size reached 14 while the minimum reached 4 using early stopping.

5 Results and discussion

This section illustrates the results obtained from the experiments conducted using the four models discussed in the previous section. Figure 7 shows the results of the four models using N-gram and unigram for different batch sizes with embeddings of dimension 300 while Figure 8 shows the results for these models with words embeddings of dimension 100.

It is shown in Figure 7 that when using embeddings with dimension of 300, the highest accuracy value reached 100%, while the lowest value reached 93.22%. However, with dimension of 100 as illustrated in Figure 8, the highest accuracy value reached 98.9%, and the lowest reached 91.6%.

These findings confirm that the embeddings of dimension 300 contain more information and thus provides better results. Furthermore, when comparing the CBOW to the Skip-gram (SG) model without considering the dimension, the results show that the highest accuracy value for the experiments that were implemented using CBOW reached 100% and the lowest was reached at 91.6%. Meanwhile, the highest accuracy value using SG reached 99.11%, and the lowest value was 92.15% as shown in Figure 7 and Figure 8. Therefore, there is no preference for using CBOW model over SG model or vice versa.



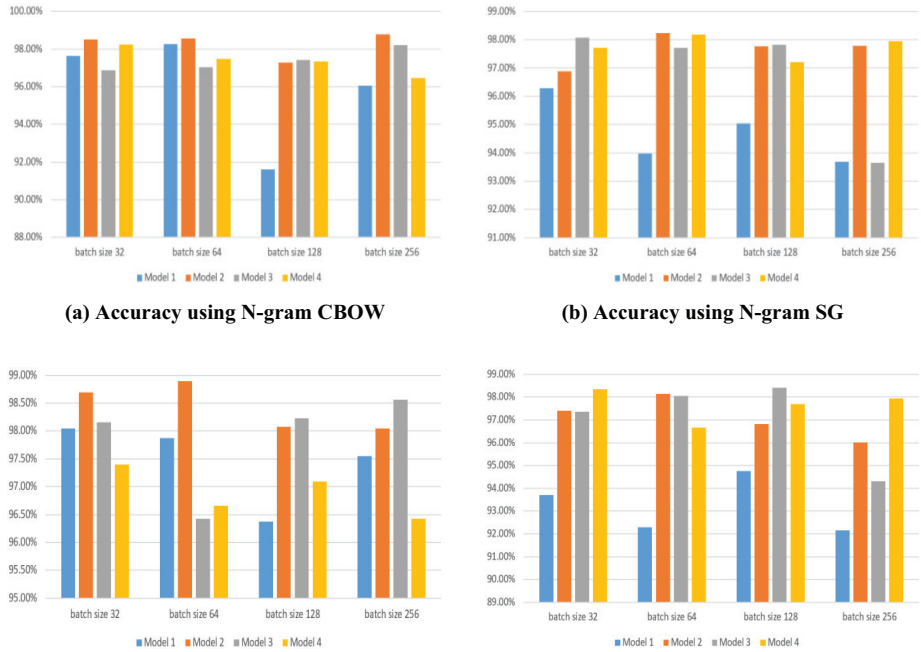
(a) Accuracy using N-gram CBOW

(b) Accuracy using N-gram SG

(c) Accuracy using unigram CBOW

(d) Accuracy using unigram SG

Fig. 7. Accuracy values using different Aravec models with dimension 300



(a) Accuracy using N-gram CBOW **(b) Accuracy using N-gram SG**

(c) Accuracy using unigram CBOW **(d) Accuracy using unigram SG**

Fig. 8. Accuracy values using different Aravec models with dimension of 100

Table 3 shows the best accuracy results while Table 4 shows the worst accuracy values for the four models. As shown in Table 3, the best accuracy among all models was obtained by model 3 and reached 100%, when using N-gram CBOW with dimension of 300, batch size of 64, and after 4 epochs. The second best accuracy value reached at 99.11% by model 1 when using N-gram SG with dimension of 300, batch size of 128, and after 6 epochs. The third best accuracy reached 98.9% by model 2, when using unigram CBOW with dimension of 100, batch size of 64, and after 6 epochs. While the last best accuracy value reached 98.69% by model 4, when using N-gram SG with dimension of 300, batch size of 64, and after 4 epochs.

Table 3. The four models sorted according to best accuracy results

Best	Accuracy	Batch Size	Epoch	Aravec Model	Dimension
Model 1	99.11%	128	6	SG	N-gram 300
Model 2	98.9%	64	6	CBOW	Unigram 100
Model 3	100%	64	4	CBOW	N-gram 300
Model 4	98.69%	64	4	SG	N-gram 300

Table 4 shows that the worst accuracy among all models was obtained by model 1 and reached 91.6%, when using N-gram CBOW dimension of 100, batch size of 128, and after 5 epochs. The second worst accuracy value reached 93.22% by model 2, when

using N-gram SG dimension of 300, batch size of 256, and after 4 epochs. The explanation is that model 2 is an updated version of model 1, where a dropout is added to the model. Model 3 reached the third worst accuracy value of 93.65% when using N-gram SG with dimension of 100, batch size of 256, and after 4 epochs. Model 3 is an update of model 2, where the number of hidden layers is increased. Finally, model 4 reached the last worst accuracy value of 95.97% using N-gram CBOW with dimension of 300, batch size of 32, and after 4 epochs. The difference between models 3 and 4 is that a CNN layer was added to the latter. To recap, we can say that adding dropout, increasing hidden layers, and adding a CNN layer enhanced the performance of the sentiment classification task of the LSTM model.

Table 4. Four models sorted according to worst accuracy results with some details

Worst	Accuracy	Batch Size	Epoch	Aravec Model	Dimension
Model 1	91.6%	256	5	CBOW	N-gram 100
Model 2	93.22%	256	4	SG	N-gram 300
Model 3	93.65%	256	4	SG	N-gram 100
Model 4	95.97%	32	4	CBOW	N-gram 300

The results also show that the use of large batch sizes does not enhance the performance of the models for sentiment classification task because the worst accuracy results are obtained mostly when a batch size of 256 is used, while 64 is the batch size of the majority of the models when the best accuracy values are achieved.

6 Conclusion

In this paper, four models based on LSTM deep learning model for sentiment classification task are studied because of its ability to capture long-term dependencies to keep historical information and try to reduce the effect of vanishing/exploding gradient. Also, we attempted to test the effect of adding a one-dimension convolutional layer to the LSTM model to extract more prominent features with Aravec pre-trained word embedding model used as the input layer. The experimental results prove that the four models improve the accuracy results of sentiment classification task effectively where the best accuracy value (i.e. 100%) is achieved by model 3, which has more hidden units and applied with CBOW embedding model with dimension of 300, batch size of 64, and 4 epochs.

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Mobile App Prototype: Telemedicine for Mental Health Care During Pandemic

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Abstract—At the end of 2019, the communicable disease COVID-19 was first detected in the city of Wuhan, China. It affected every country in the world. The Peruvian government announced quarantine and social distancing measures to prevent the spread of the virus. As a result of the measures implemented economic and social well-being of people were affected causing an increase in stress, depression and anxiety, which are emotional disorders that affect mental health. Added to this is the lack of access to mental health services. The objective is to develop a telemedicine mobile application prototype for mental health services based on android. The methodology applied was Rational Unified Process (RUP) methodology because it allows documenting, ordering and structuring software development. The result obtained was a prototype of a telemedicine mobile application with a design and functionalities that make access easy for patients and specialist to mental health services. The quality of the prototype was evaluated through the judgment of experts, who assessed its efficiency, usability and security Obtaining after the calculation, 4.66 average or mean; this indicates that according to the established quality range, the quality of the mobile prototype is high. In conclusion, it was possible to develop an efficient, easy-to-use and safe mobile telehealth prototype that provides a solution facilitating patient access to mental health care services for their emotional, psychological and social well-being.

Keywords—mobile application, COVID-19, emotional, RUP, psychological, mental health, social, telemedicine

1 Introduction

Currently, the infectious disease COVID-19, caused by the new SARS-CoV-2 coronavirus was first detected in Wuhan, China. Since then, the virus has affected global society, including Peru, spreading at an accelerated rate, having a catastrophic effect worldwide [1], [2]. The international community and local governments were forced to implement restrictions and social distancing as measures to minimize the spread of this new coronavirus [3], [4]; as a consequence of these measures implemented, economic

and social activity was affected causing an increase in anxiety, stress and depression in people around the world, as these are effects of emotional disorders that specially affect mental health [5]. Since pandemic, health services were one of the most affected sectors by the demand for medical attention, which prevented patients from receiving suitable care [6]. In addition, the COVID-19 pandemic is an unpredictable condition. As the virus is constantly changing due to a mutation that generates a new viral variant which is potentially contagious and it goes along with a great deal of uncertainty [7]. As a consequence, individuals with pre-existing conditions and poor health status are vulnerable to health sequelae and are associated with an increased risk of poor mental health during pandemic [8]. Therefore, interventions to soften the psychological impact caused by pandemic illness are urgently needed. That it is still unknown whether mindfulness practice can protect against the harmful emotional effects of a pandemic crisis such as the one recently experienced with COVID-19 [9]. Thus, the research work offers the solution to the problem through a mobile telemedicine or telehealth app based on the Android operating system, applying the RUP methodology (since this methodology provides a structured way for visualizing the software development process); By having this type of technology, there is no need to go to the healthcare service providers. Which is very convenient, especially for those people who have a tight schedule or have difficulty moving around easily. It also makes health service more accessible to those who have been unable to access mental health services, including people in emergencies, no matter where they are. Likewise, the study opens doors to new opportunities benefiting all those who require help, consultation or psychological care. It also facilitates access to mental health services without the need to leave home or go to the hospital, clinic or healthcare facility or without the specialist coming to your home. In addition, it helps mental health specialist to provide immediate care to their patients remotely and in real time through video calls for the benefit of the patient's emotional, psychological and social well-being. After analyzing the problem under study, the following question is addressed: To what extent can the mental health treatment of people in times of pandemic be improved?

The objective of the research is to develop a prototype of the Android-based mobile telemedicine application, using RUP methodology; for mental health services for the benefit of emotional, psychological and social health well-being of people in times of pandemic.

In section 2, the article reviews the literature related to the research work, in Section 3, the established methodology is defined, in Section 4, the development of case studies of the research; Section 5, introduces the results achieved with the research; in Section 6, the discussions; and finally, in Section 7, the conclusions and future work.

2 Literature review

In this section, the topic of the mobile application for the mental health service through telemedicine was approached; therefore, different scientific articles related to the research work were investigated, where they provide us with their observations and results achieved.

Authors, Miranda et al. [10], argue that telemedicine helps to solve the problem of limited access to health services, especially in times of pandemic, such as COVID-19. Therefore, their research objective is to develop a telemedicine application based on mobile applications that help people obtain health services under the design method, the cascade model. The results showed a positive response to the telemedicine mobile application by the public to access health service during the pandemic. In this sense, the telemedicine technology through the mobile application allows accessing the health service remotely no matter where they are.

On the other hand, authors Mulgund *et al.* [11] conducted a study with the aim of designing, developing and evaluating a telemedicine platform (mobile application for patients, web application for providers, dash-board for reports and a chatbot) called Ognomy, for patients with sleep apnea. The method applied is the design science methodology. Similarity, to collect information they conducted a brainstorming workshop and interviews with 6 experts for requirements gathering. The results demonstrate the successful application of the telemedicine platform for sleep apnea patients and their providers. Definitely, it is very important to have expert judgement to develop this type of technology, as the authors of the research did.

Likewise, authors Hwang and Jo [12] conducted research for the development of a telemedicine system for therapy and monitoring of patients' eating disorders. To contribute to the solution, they developed vital tools for both patients and caregivers. As a result, a mobile application that updates patients' medical and psychological statuses was developed to access phycological counseling services for patients with emergency and social anxiety. With this type of application, as the authors of the research realized, it is possible to follow up and provide counseling to patients in timely manner, which is very important for their mental well-being.

Similarly, author Hodges, [13] conducted a study with the objective of exploring the creation and development of a mobile health care (telemedicine) application. To do this, he conducted a study of a rural health plan that has low income in southwest Georgia. The telemedicine platform was developed with the purpose of simplifying health care access and medical appointment scheduling electronically between consumers and providers to reduce long term health care costs. Finally, the contributions of the study include the development of methods to reduce the assimilation gap associated with the use of the adopted platform. It is important to highlight that telehealth not only allows access to health services but also reduces the cost of care, which benefits low-income people, as presented by the author in his research.

Authors Lahti et al. [14], argue that in low- and middle-income countries such as South Africa and Zambia, the high prevalence and mental illness of youth is higher than in other high-income countries. They also claim that many professionals lack knowledge of youth depression. Therefore, their aim is to develop a mobile application for mental health assessment to provide youth with access and appropriate health care in South Africa and Zambia. The method applied is the mixed multicenter study design. The result evidences that the mobile app improves the depression care provided to young people in Sothern Africa and Zambia. It is unfortunate that young people have depression problems that damage their mental health, especially in emerging countries. However, the application of telemedicine helps to mitigate this type of problem for the welfare of society.

In addition, authors Ardi et al. [15] state that, during university education, many students experience changes related to their mental health condition. To this is added academic stress, personal-emotional problems, etc. That obstructs their mental health development, to which, COVID-19 pandemic increased changing social life. Therefore, the study aims, to develop and validate an Android-based online psychological assessment mobile application for monitoring students' mental health. Data analysis was performed using Aiken's V coefficient test, confirmatory factor analysis and Rasch model analysis, and ten experts in counseling and software development. The results show that the application effectiveness is very good in mapping students' mental health conditions. However, it is not only enough to map the mental health of university students, but it is also necessary for the telemedicine application to provide real-time support through video calls in order to provide a better solution to the mental health problem.

On the other hand, the authors Rashid Soron and Chowdhury [16] mentioned that in Bangladesh, people do not have easy access to mental health care services due to lack of specialists. Therefore, to solve the problem they designed, developed and implemented "Monerdaktar" a web application and mobile application. For this, they used literature review and observation of mental health service provided in hospitals in Bangladesh. According to the feedback from patients, mental health specialist and IT professionals, they developed the prototype web and mobile application. The result shows, the opportunity to connect remotely health specialist, both psychiatrics and clinical psychologists. In addition, during COVID-19 pandemic, Monerdaktar provided free access to more than 700 patients. Finally, the Monerdaktar app solved the problem of access to mental health care in Bangladesh from anywhere. It is very important to collect and take into account the feedback from patients, psychologists, etc. to develop the app, as the authors did.

According to the author, Johnson [17], the mobile application is important to address the mental health problem, and states that there were few successes in this area. Therefore, the purpose of his research is to design a mobile application to use during mental health crisis, using a user-centered design approach. He developed in three phases: In phase 1, he gathered information; in phase 2, he built a prototype based on the first phase; in phase 3, he conducted testing. The results of phase 1 and 3 analyzed with qualitative and quantitative method. The main finding was that the need for support focuses on crisis awareness. Finally, the construction and operation of the Connections mobile application was conducted guided by the finding. Definitely as the author mentions, currently there is not much success of telemedicine because of little research in this field for mental health.

On the other hand, the authors Islam et al. [18] argue that, crisis caused by COVID-19 pandemic has an alarming effect on mental health in all the affected countries, and state that, attention has not been taken as it should be in developing the digital solution to provide mental health support, especially in Bangladesh. Therefore, the objective of the study was to gather the requirements and develop a digital solution based on a mobile application to provide mental health support to the people of Bangladesh. They developed in three phases: one, gathering the requirements through semi-structured interviews with 37 participants; two, the design and development of the mobile application called 'Muktomon' [open mind] was conducted; finally, the usability and usefulness was evaluated. The results achieved show that the application is usable and useful for

the mental health service during pandemic. Definitely as the author states, the ongoing pandemic has affected and is affecting mental health, and digital solutions have not been developed adequately.

Similarly, authors Callan et al. [19] developed a mobile application called CBT MobileWork, which promotes the practice of CBT skills for the benefit of mental health. For this, they applied a user-centered design method, where 8 depressed patient and 5 therapists participated to carry out the initial development and testing. Then, they conducted an evaluation with 15 patients and their therapists, for completeness. The results show that the application satisfies the patients and therapists, who rated it as very useful during testing. Finally, the CBT MobileEork mobile app has feasibility and benefit patients in their mental health. Definitely, the app not only benefits the patient but also the caregivers by facilitating access, especially in times of pandemic.

In conclusion, the authors propose solutions that allow monitoring the status of patients according to the data collected. In the same way, for online appointment registration, online mental health assessment and psychological counseling. Above all, it facilitates access to mental health services. However, on the above-mentioned solutions, the function of the applications is not for real-time patient monitoring by specialists. This research will enable the implementation of a mobile telemedicine application based on real-time monitoring for the well-being of people's mental health.

3 Methodology

This section will focus on defining the steps or phases of RUP methodology and the development tools that allowed the development of the prototype mobile application that provides society with a solution to the problem of lack of access to mental health services during the COVID-19 pandemic.

3.1 RUP Methodology

RUP is a software development methodology, focused on object-oriented, used to carry out projects efficiently and develop quality software. According to the authors [20] RUP is an iterative and incremental software development method based on the architecture, and in turn, during the software development involves the customer, to achieve the result according to the customer's wishes. It is distributed in 4 phases which are, Inception, Elaboration, Construction and Transition. Figure 1 shows the process flow of the RUP methodology.

Inception. In this first phase, the scope of the project is defined and focused on the business model and its requirements. Likewise, the initial risks associated with the project are identified, and the general vision of the software architecture is detailed, as well as the subsequent iterations.

Elaboration. In this second phase, the selection of use cases that help or allow the definition of the system's base architecture is carried out. In the same way, the specification of each of the selected cases and the analysis model of the system is carried out.

Construction. In this third phase, the development team carries out the construction of the system through a series of iterations, for which some System Use Cases

are selected. The design is made and its implementation is carried out, and then the respective tests are performed for the transition stage.

Transition. In this last phase, it is ensured to guarantee that the product is available and well prepared to be delivered to the final user. For this, the adjustment of errors and defects found during the testing stage is performed.

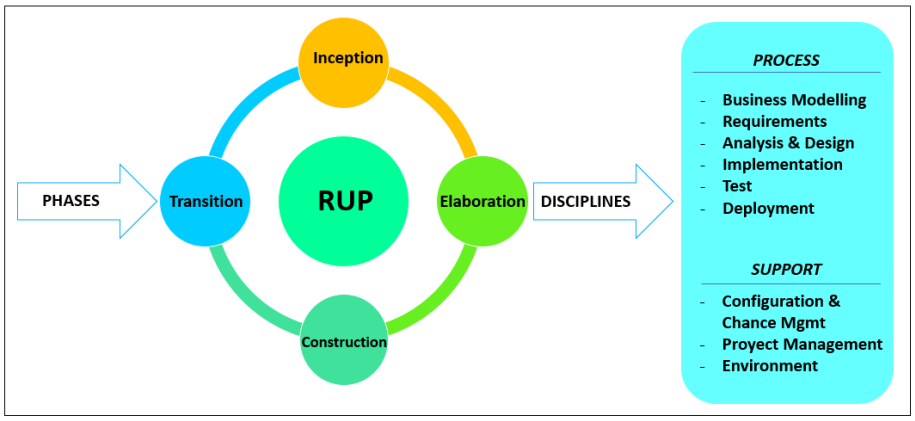


Fig. 1. RUP methodology flow

3.2 Development tools

This section defined all the tools used to develop the prototype of the mobile telemedicine application to provide mental health services to people.

Star UML. It is a tool to visual software modeling that allows the creation of Unified Modeling Language (UML) diagrams. According to the author [21], it is a software that describes the UML, with which you can create processes or flows such as use case diagrams, etc. to understand the system model.

Figma. It is a cloud-based design tool, i.e., an online tool; which serves to design user interfaces collaboratively in real time. According to the authors [22] it is a vector graphics editor and a web-based prototyping tool.

Android studio IDE. It is an official IDE for developing Android OS mobile applications; which is specially designed to speed up development and help create high quality applications. According to the author [23] Android Studio IDE provides tools for creating apps for any Android device; it includes code editing, debugging, and flexible compilation for creating and quality apps.

Kotlin. It is a programming language officially annealed by Google for Android app development; it supports object-oriented and functional programming for mobile application development. It allows less code to be written and is compatible with Java. According to the authors [24] it is a new programming language, as an alternative to Java and is oriented to Java Virtual Machine (JVM), it is able to solve already known limitations of Java language.

Firebase. It is a cloud-based platform for creating mobile and web applications, seeking to make the development of applications for mobile and web devices faster, without sacrificing the quality of the app. According to the author [25] Firebase is a platform for the development of mobile and web applications that includes tools and infrastructure with which developers can create high quality applications.

MySQL. MySQL is a relational database management system, based on structured query language (SQL) and client-server model. It is very fast, uses several layers of security and is cross-platform. Above all, as the author states [26] MySQL is simple to configure and easy to use.

4 Case study

In this section, the selection and development of each of the phases of the selected methodology was carried out.

4.1 Comparison of methodology

This section introduces the evaluation of the methodologies between RUP, Mobile-D and Test-Driven Development (TDD) to determine which one is the most suitable for developing the proposed mobile application prototype. The evaluation was performed on a scale of 1 to 5. Where, 1 indicates that the methodology in terms of the evaluative condition is not suitable for developing the prototype, and 5 indicates favorable for the development of the project. As can be seen in Table 1, the RUP methodology has a total score of 23, the Mobile-D methodology has a score of 16 and the TDD methodology has a score of 17. In conclusion, from the results obtained, we can say that the RUP methodology is the most suitable for developing the proposed mobile application, since it has a higher score than all the methodologies evaluated.

Table 1. Comparison of methodologies

Evaluative Condition	**Methodology**		
	RUP	**Mobile-D**	**TDD**
	Score	**Score**	**Score**
Available budget	3	4	2
Project size	5	3	4
Limited delivery times	2	2	3
Need for documentation	5	2	3
Personnel required	5	2	2
Adaptability and response to changes	3	3	3
Total Score	**23**	**16**	**17**

Next, each of the phases of the methodology selected through the evaluation is developed.

4.2 Inception

Business modeling. In this section the abstract description of the business was made to understand the processes to develop the mobile telemedicine application.

Business use cases. This section introduces the business use diagram. As shown in Figure 2, the interaction of the actors (Patient, Assistant and Mental Health Specialist) with the business use case is visualized in a general way.

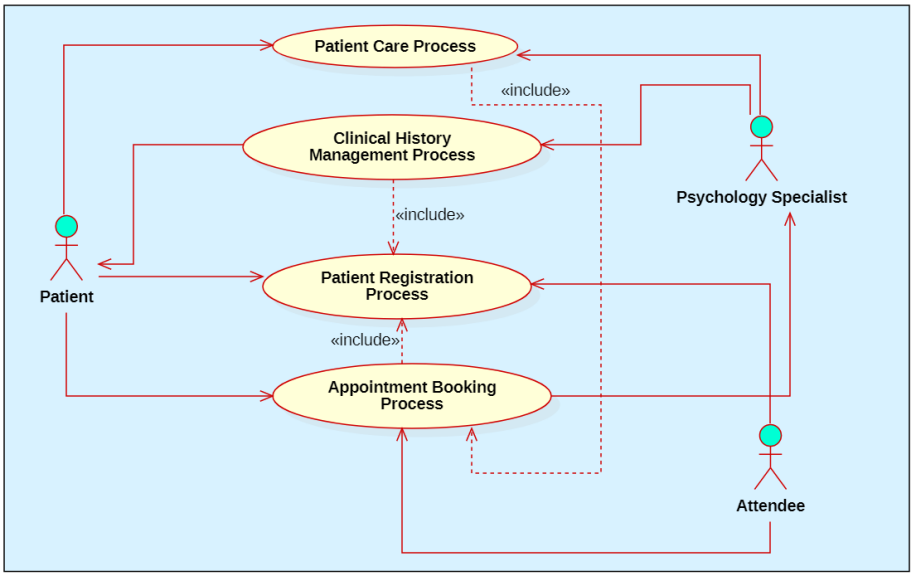


Fig. 2. General diagram of business use cases

Business activity diagram. This section presents the business activity flow diagram. As shown in Figure 3, it visualizes the flow of activities performed by the patient, Assistance and Mental Health Specialist, from appointment booking to completion of patient care.

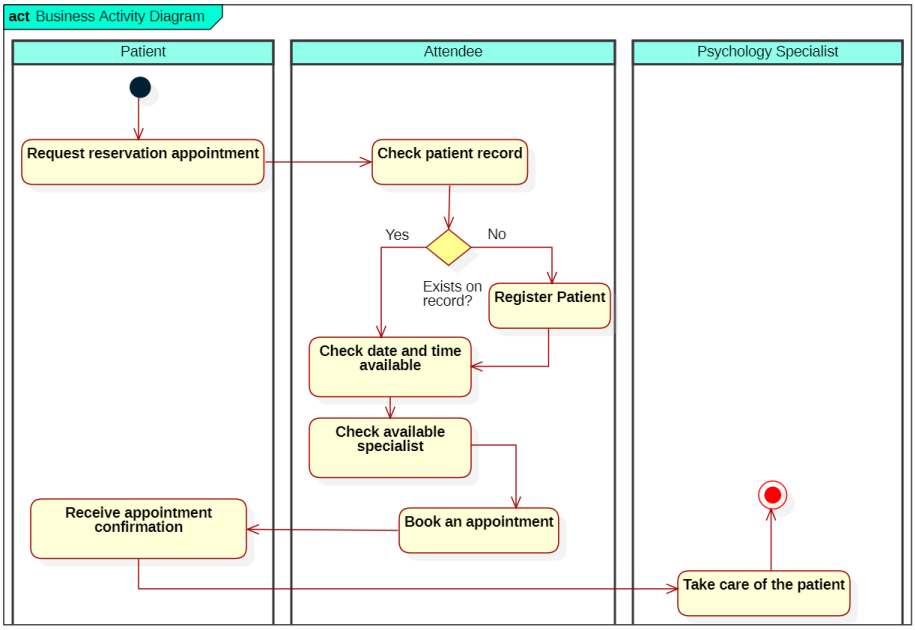


Fig. 3. Business activity diagram

Requirements capture. In this section the identification of the system's functional and non-functional requirements was performed.

Functional requirement. This section shows the functional requirements of the system, which define the function of the mobile application. As shown in the Table 2, sixteen identified functional requirements are shown, with their respective use cases and priority.

Table 2. Functional requirement

ID	Functional Requirement	Case of Use	Priority
RF1	Allow the user to authenticate.	Authentication	High
RF2	Allow to create new account.	Create Account	High
RF3	Allow to confirm the authenticity of the user when creating the new account.	Confirm Registration	High
RF4	Allow managing the profile (edit or update and delete).	Manage Profile	High
RF5	Allow to see the profile of the specialist in psychology.	See Specialist Profile	Medium
RF6	Allow managing the patient's clinical history.	Manage Clinical History	Medium
RF7	Allow sending messages via chat (text, files and audio).	Send Message	High
RF8	Allow start video call.	Start Video Call	High
RF9	Allow to register appointment reservation.	Book Appointment	High
RF10	Allow entering data for appointment booking.	Enter Patient Data	High
RF11	Allow selecting the available date for appointment reservation.	Select Date	High
RF12	Allow selecting the time available for appointment booking.	Select Time	High
RF13	Allow to cancel the appointment reservation.	Cancel Medical Appointment	High
RF14	Allow selecting the specialist in psychology to book an appointment.	Select Specialist	High
RF15	Allow to search for the specialist in psychology.	Find a Specialist	High
RF16	Allow the psychology specialist to be shown in the list.	List Specialist	High

Non-functional requirement. This section presents the non-functional requirements of the system. As shown in Table 3, ten non-functional requirements were identified, with their respective priorities. For this purpose, they are classified into three types: efficiency, security and usability.

Table 3. Non-functional requirement

Classification	ID	Description	Priority
Effectiveness	RNF1	The response time of the request must not exceed 3 seconds.	High
	RNF2	The video call connection should not generate slowness when connecting.	High
	RNF3	The application to be easy to run.	Medium
Security	RNF4	The application must keep the stored data safe and secure.	High
	RNF5	The app must not display ads.	High
	RNF6	Access to the application must be only for registered users.	High
Usability	RNF7	The application must be easy to use.	Medium
	RNF8	The application requires use of camera and audio.	High
	RNF9	The application interface must be friendly and intuitive and of quality.	Medium
	RNF10	The application must provide contact information for the clinic.	Medium

4.3 Elaboration

System use case diagram. This section presents the system use case diagram. As shown in Figure 4, the interaction of the system actors (Users) with each of the system use cases is visualized. The patient actor is the person who requires help or performs a mental consultation for emotional, psychological and social well-being, and the Specialist actor is the person who provides care to the patient.

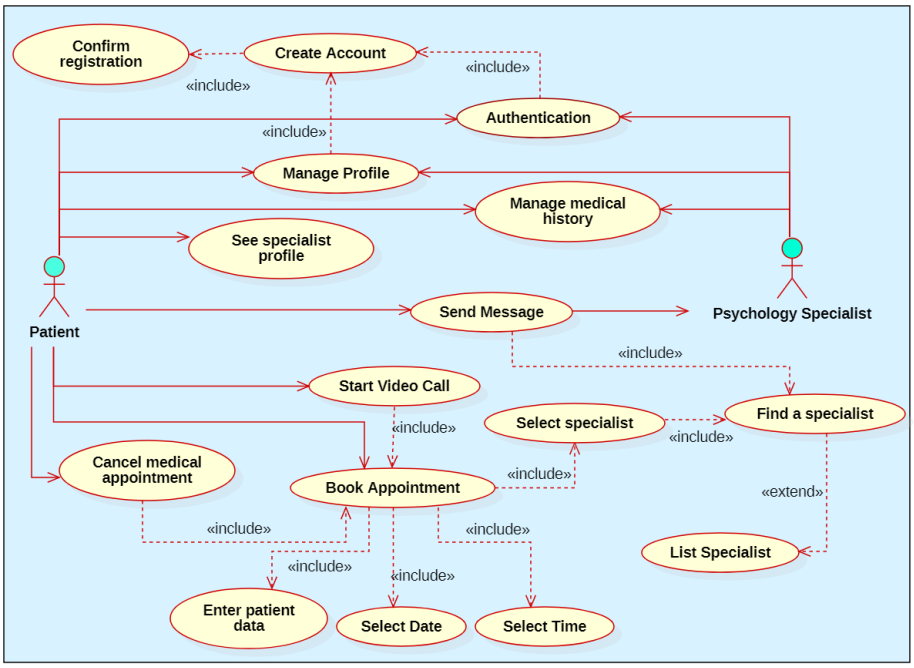


Fig. 4. General diagram of system use cases

System activity diagram. This section presents the flow diagram of the video calls through the mobile application; as shown in Figure 5, which illustrates the flow of activities performed by the patient, the mental health specialist and the mobile application, for the mental health care of the patient, from the beginning to the end of the video call.

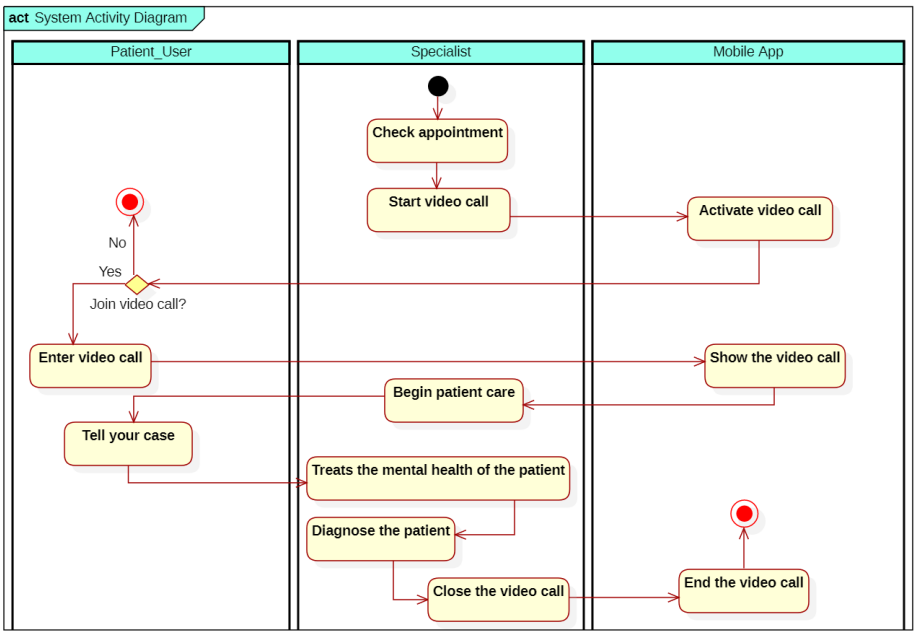


Fig. 5. System activity diagram – video call

4.4 Construction

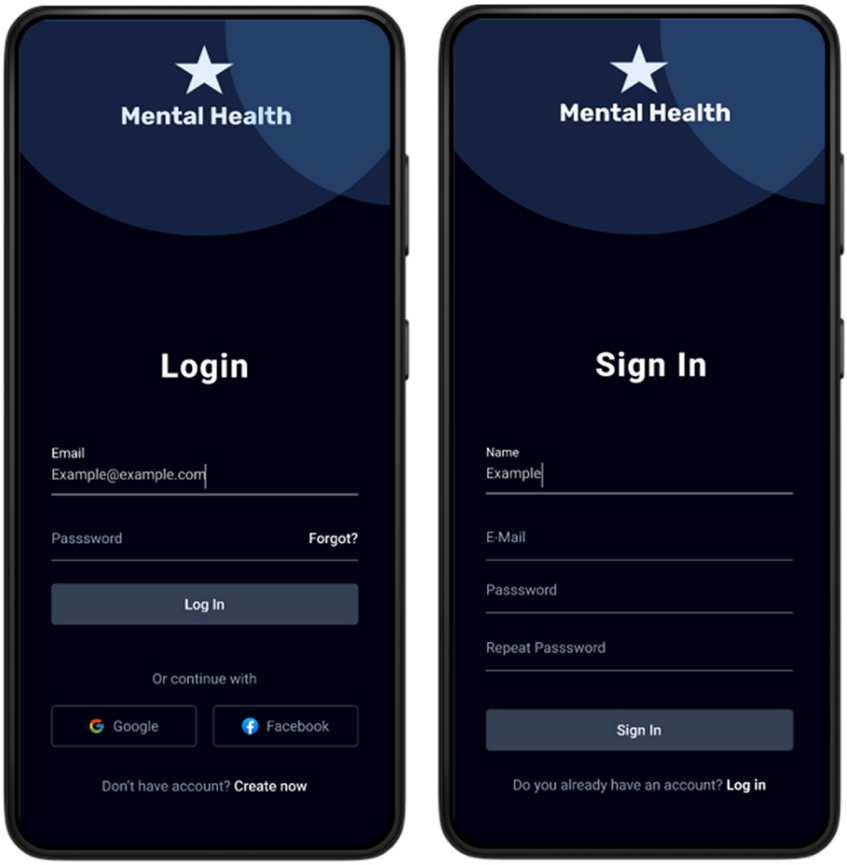
Mobile application prototype. In this section the prototype of the mobile application was built as shown in the following figures:

As shown in Figure 6a, the login prototype is illustrated, where the user (patient) can log in by entering their email and password. They can also log in with Google or Facebook accounts. Figure 6b shows the prototype of creating a new account (registration), entering the requested data and verifying authenticity with a code sent to the e-mail address provided at the time of registration. Since to enter the mental health service it is necessary to log in and have a registered account.

As shown in Figure 7, the prototype of the main menu is displayed, which makes it easier for the user to access his or her registered appointments or to be aware of pending or upcoming appointments, since the main menu shows the user's pending appointments. In the same way, it shows the list of the most prominent specialists, which facilitates the booking of their appointments.

Similarly, as shown in Figure 8a, the list of mental health specialists and the search prototype are displayed, allowing the patient to search for the specialist of his choice by entering his name in the search engine. It also allows the patient to save the appointment reservation. Figure 8b shows the prototype appointment card, where the patient can enter his or her data, the date and time available to the specialist, and save.

Figure 8c shows the prototype of the registered appointment list, where the patient can filter the pending appointments (There are more than two pending appointments) by entering the date in the search box. Likewise, join the video call according to the time and date scheduled in your appointment booking with the mental health specialist of your choice, or cancel the appointment, if desired.



(a) **(b)**

Fig. 6. Login and create a new account

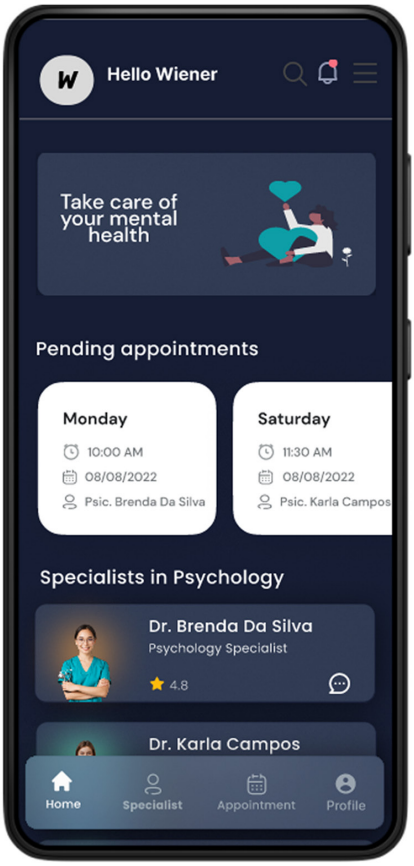
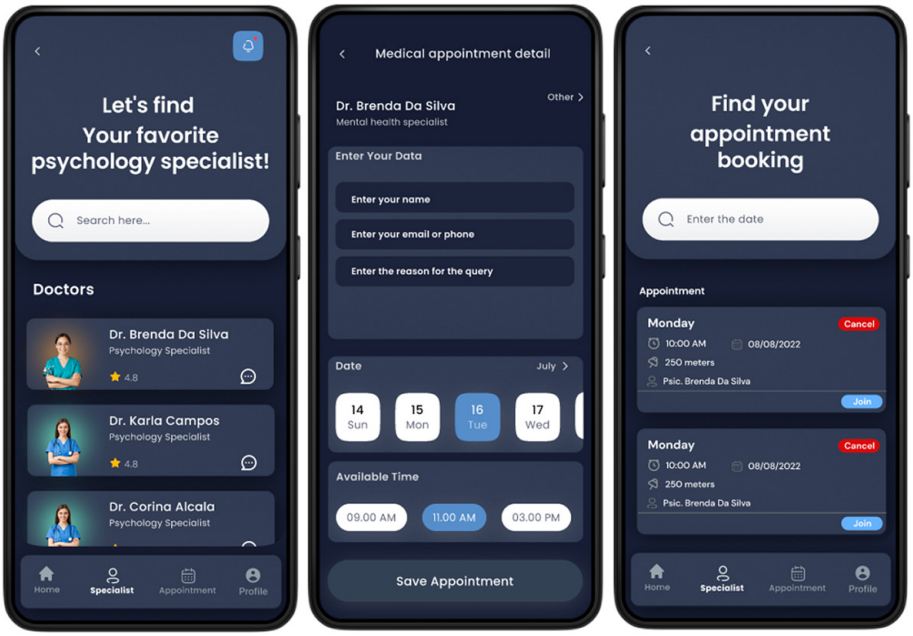


Fig. 7. Main menu prototype



(a) **(b)** **(c)**

Fig. 8. List and search specialist, record appointment reservation, saved appointment reservation list

As shown in Figure 9a, the video call prototype is visualized, since by this means the specialist can attend the patient's consultations live and in real time about his or her mental health for the benefit of the patient's emotional, psychological and social well-being; therefore, it is very important to initiate a video call to treat or provide care to the patient. Likewise, as shown in Figure 9b, the chat prototype is visualized, where the specialist and the patient interact through the use of text message, audio, etc.

(a) **(b)**

Fig. 9. Video call and chat prototype

5 Results

5.1 About prototypes

A prototype of a mobile telemedicine application for mental health services based on the Android operating system was developed to work in mental health care organizations (hospitals, clinics, etc.). As shown in Figures 6, 7, 8 and 9, the prototype has functionalities for logging in, creating a new account, searching for mental health

specialists, and registering a consultation or booking a medical appointment electronically or online. It also has video calls and chats that make it easier for specialists to treat patients remotely and in real time for the benefit of mental health wellness. Likewise, it has functionalities designed so that users (patients) can visualize their data or medical records. In addition, communicate with the mental and emotional health specialists of your choice. Above all, it reduces the cost of care and improves access to mental health services.

5.2 About the people survey

A total of 60 people were surveyed online to learn about the mental health services received since the start of the COVID-19 pandemic and their perception of the mobile telemedicine application; six questions were asked for the survey (see Table 4) with response options based on the Likert scale: 1 (Never), 2 (Almost never), 3 (Sometimes), 4 (Almost always) and 5 (Always). The validation of the survey instrument was carried out by five experts, obtaining an average result of 80%. For the survey to be valid, it must have an average score above 75%, thus fulfilling the validation by content, evaluating the criteria of clarity, relevance and coherence, and responding with a Likert-type scale from 1 to 5; where 1 is equal to 20% and 5 is equal to 100%.

Table 4. Questions raised

ID	Questions
Q1	Have you received mental health services in-person since COVID-19 pandemic started?
Q2	You have little time and difficulty getting to the mental health care center.
Q3	Would you receive mental health services through the mobile telemedicine application?
Q4	Do mental health services through the telemedicine mobile app impact your safety?
Q5	Does the mobile telemedicine application improve access to mental health services?
Q6	Is consultation via telemedicine mobile app an acceptable way to receive mental health care?

According to the results obtained as shown in Figure 10, in question Q1, 100% of the respondents indicated that they never received mental health service since the COVID-19 pandemic began. Likewise, in question Q2, 73% (44 of the 60 respondents) indicated that they always have tight time and difficulties to travel to the mental health service center. Similarly, in question Q3, 50% (30 of the 60 respondents) indicated that they would always receive mental and emotional health service through the mobile telemedicine application. Furthermore, in question Q5, 52% (31 of the 60 respondents) indicated that almost always the mobile application improves access to mental health services.

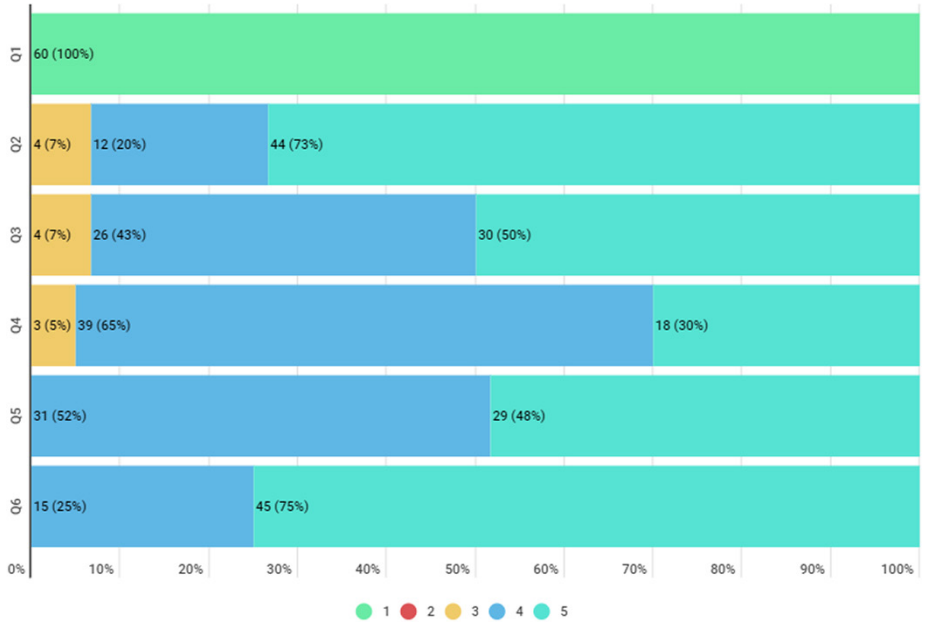


Fig. 10. People survey result

5.3 Validation by expert judgment

This section presents the results of the evaluation of the quality of the mobile application prototype, validated by ten experts in the design and construction of health-oriented mobile applications. The evaluation criteria are the following: efficiency, usability and security. The questions to validate the quality of the prototype were based on a Likert scale, with the following response options: 1 (very low), 2 (low), 3 (regular), 4 (high) and 5 (very high); Table 5 shows the result of the validation by the experts, as well as the evaluation questions used for each criterion; likewise, the level of quality, achieved from the calculations obtained by the mean and standard deviation (S. D.) of each question; From the results of the validation by the experts, the quality level was calculated as follows: 1 (very low), 2 (low), 3 (regular), 4 (high) and 5 (very high); Table 4 shows the result of the validation by the experts, as well as the evaluation questions used for each criterion of each question; according to the average, the quality level of the prototype of the mobile application was rated, with a scale ranging from 0.00 to 2.00 (Low), 2.01 to 4.00 (Medium), and 4.01 to 5.00 (High). According to the results, a total mean of 4.66 with a standard deviation of 0.465 was obtained, which means that the level of quality that includes the criteria of efficiency, usability and security of the mobile application is high.

Table 5. Validation results by experts

Criterion	Questions	Mean	S. D	Quality
Efficiency	The app is compatible with older and newer versions of Android.	5.00	.000	High
	The app is compatible with old and new versions of Android.	4.60	.516	High
	Video call quality without interruptions.	4.60	.516	High
	Improved access to mental and emotional health services.	4.80	.422	High
Usability	The app is easy to use.	4.80	.422	High
	The app's interfaces are user-friendly and intuitive.	4.80	.422	High
	The app interfaces are of excellent quality.	4.40	.516	High
	The app has settings to change theme, font type and font size in case of visual impairment of the patient.	4.50	.527	High
Security	It has authentication mechanism and user session control.	4.80	.422	High
	The video call and chat are end-to-end encrypted.	4.40	.526	High
	The app keeps stored data safe and secure	4.70	.483	High
	Stored user data is manipulated only by the user owner.	4.80	.422	High
Average and total standard deviation of quality level		**4.66**	**.465**	**High**

6 Discussions

The methodology used in the research to develop the telemedicine mobile application prototype is the RUP methodology. However, the methodology used in the authors' research [10] is different from ours, since they used the waterfall methodology to develop their prototypes. Regarding the evaluation of the prototype, in our research it was performed through validation by expert judgment who evaluated the prototype according to their knowledge in the design and development of the mobile application, which was then rated the level of quality with a scale: low, medium and high according to the average obtained after the calculation of each question that composes the evaluation criteria. Meanwhile, the authors [19] conducted the evaluation of the prototype with 15 patients and their therapists, who rated whether the prototype met their expectations according to the function tests of the app. Regarding the prototype, the authors [15] developed a mobile app for online psychological assessment and monitoring the mental health of college students. Meanwhile, our prototype of the mobile application is focused for all people, which, at the same time, facilitates mental health specialists to provide care via video call to people who require help for the welfare of their mental and emotional health.

Although it is true, the research carried out is at the technical level of the prototype. However, from a general point of view, psychological factors such as lack of affection can directly affect mental health. In addition, the biological factor represents a significant aspect of mental health, since bad life experiences, inadequate lifestyle, and family history of mental health problems, among others, can negatively affect mental health, harming the person's health.

7 Conclusion and future work

In conclusion, this research has succeeded in developing a prototype of a mobile telemedicine application to provide mental services; for the emotional, psychological and social well-being of people. A prototype of quality, efficient, easy to use and safe; to provide care to people who require help. For the benefit of their mental health and well-being. The development of the prototype has contributed to the mental health of people in Peruvian society, facilitating remote access to services without leaving home and no matter where you are in difficult times such as the COVID-19 pandemic. This forced them to maintain social distancing, which made it difficult to travel to mental health care centers. To achieve the purpose, the RUP methodology; was of Vital importance as it allowed to efficiently document and develop the prototype of the mobile application.

One of the limitations encountered during the development of the prototype are the risks related to the use of data and the security of information, privacy and confidentiality of users. Similarly, the hardware imposes restrictions, since the design of the mobile application must be compatible with a wide range of high-end, mid-range and low-end mobile devices.

In future work, it is suggested to complement this project with emerging technologies, such as artificial intelligence, to support the diagnosis of the patient's mental state. Similarly, to develop the proposed mobile application for mobile devices with the IOS operating system.

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